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KHANNA'S
CIVIL ENGINEER'S
READY RECKONER

BY

GOVIND BHAGWANDAS KANUGA

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FOREWORD

by

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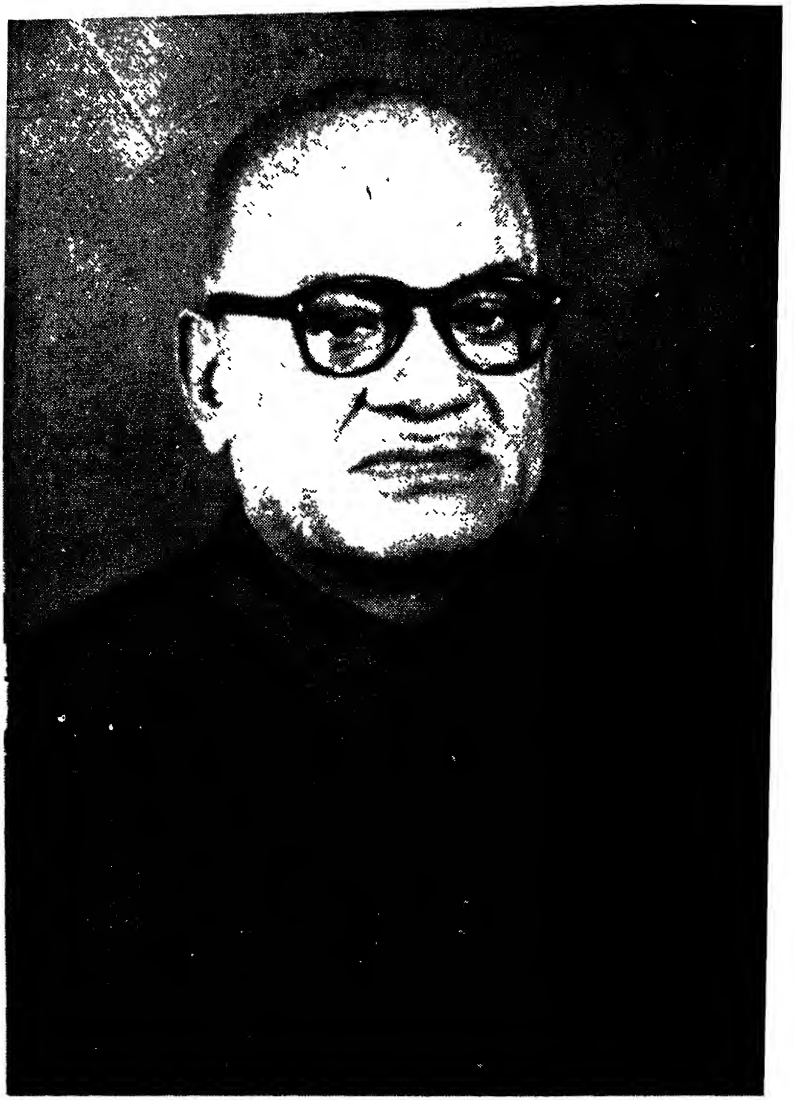

SHRI R. K. BATRA
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FOREWORD

There are quite a few Pocket Books at present for use of Civil Engineers and they do useful service from practical point of view. However quite often it has been felt by Engineers that most of these Pocket Books include certain subjects, which are hardly of any assistance in dealing with everyday *practising* of Engineering points.

The Author of this POCKET BOOK has evidently realised that omission of such subjects will help in reducing bulk but not practical utility. Again the author has evidently in view large number of beginners, especially of Sub-Overseer and Overseer class, who do not use a Pocket Book but merely a reference book ; but also for use as manual in Engineering for them to work out practical problems.

The author, Shri Govind Bhagwandas Kanuga, deserves congratulations for his laudable efforts and I feel confident that all interested will take advantage of this new POCKET BOOK.

Sd. R.K. BATRA,
I.S.E.,
Retired Chief Engineer,
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Jubbulpore.

A WORD TO ENGINEERS

The secret of success as an Engineer and to get the work done from the labour, to adjust ourselves with our fellow men, our superiors and subordinates is more important for an Engineer, than for any other man, as Engineers have to face all sorts of difficulties and also have to build the nation. If other people's behaviour acts on our nerves, like a sand paper, or if our own manners constantly cause irritation to others, there will be the failure of an Engineer.

To those young Engineers, who are new in the practical field of life, to be polite may appear arbitrary and unnecessary but in reality, they have all been formulated with one purpose —that of making others as comfortable as possible, to get as much work as possible.

The True Engineer is one who is courteous and considers what effect his speech or actions have on the person or persons with whom he has to deal. *There is a natural courtesy which is of more value than any code of manners*, but unless we are experienced Engineers we often commit blunders which though quite unintentional, may cause embarrassment to ourselves, our bosses, our subordinates, labourers, workers and our associates. It is therefore more important for an Engineer to be more courteous in all respects. "*If you want to gather honey, don't kick the beehive.*" The Engineer, who can do this, has the whole world with him. He who cannot walk, has a lonely way to failure.

Govind B. Kanuga

PREFACE

This book is a collection of most uptodate valuable information and practical data for field as well as design works.

The object of this book is to give complete, concise account of various subjects, which constantly confront the Civil Engineer in particular and practical man in general.

This book will be very useful for Engineers in the office or in the field without wading through numerous books on each subject. All efforts have been made to make it comprehensive and complete.

In plain simple language and easy tables, this compilation contains day-to-day problems of Civil Engineers.

I hope this book will be of great service to various Engineers in Government as well as in private fields, in India and abroad.

Govind Bhagwandas Kanuga.

KHANNA'S
CIVIL ENGINEER'S READY RECKONER

CONTENTS

NOTES FOR GUIDANCE

CHAPTER I

WEIGHTS AND MEASURES

1. Indian and English Weights

(a) Indian Weights.

12 Mashas	1 Tola = 2·106/175 Drams.
5 Tolas	1 Chhatak = 2·2/35 Ounces.
4 Chhataks	1 Pawa.
4 Pawas	1 Seer = 2·2/35 Pounds.
40 Seers	1 Maunds = $82\frac{2}{7}$ Pounds.

(b) English Weights.

16 Drams	1 Ounce.
16 Ounces	1 Pound.
14 Pounds	1 Stone.
2 Stones	1 Quarter.
4 Quarters = 112 Lbs. =	1 Cwt.

20 Cwt = 1 ton = 2240 lbs = 27·22 maunds

(c) Indian Weights Converted in English and English in Indian.

Indian to English

1 Maund	82·2/7 Lbs.
100 Maunds	3 673 tons.

English to Indian

1 Cwt	1 Md. and 15 Seers.
20 Cwt	1 Ton = 27 22 Maunds.

Conversion Table

Seers to Lbs (Pounds)	Multiply by 72/35.
Maunds to Cwt	,, ,, 36/49.
Tons to Maunds	,, ,, 27·1/2.

2. Misc. Measures

12 Nos	1 Dozen.
20 Nos	1 Score.
12 Dozens	1 Gross.
(24 English or 25 U.S.A. Papers	1 Quire.)
20 Quires	1 Ream.

3. Lineal Measurements (British)

Sign of Inch ″
Sign of Foot ′

7·90 inches	1 Link.
12″	1′.
3′	1 yard.
5½ yds = 25 Links =	1 rod or pole.
40 poles = 220 yds	1 furlong = 660′
22 yds = 100 Links	4 Poles = 1 Guster Chain = 66 ft.
10 Chains	1 Furlong = 660 ft.
8 Furlongs	1 Mile
80 Chains	1760 yds = 5280 ft.

4. Square Measurements

144 Sq inch	1 Sq ft.
9 Sq ft	1 Sq yd.
30¼ Sq yds	1 Sq pole or Rod.
40 Sq poles	1210 Sq yds.
4840 Sq yds	43560 Sq ft. = 1 Sq acre.
640 Sq acres	1 Sq mile.

Note : (*i*) One Acre = 208·71′ on each side of Square Acre.

(*ii*) 1600 Sq yds	1 Bigha (Bengal)
3·1/40 Bighas	1 Acre.
1961 Bighas	1 Sq mile.

5. Capacity

8 Drams	1 Ounce.
200 Ounces	1 Pint = 1¼ lbs of Liquid

8 Pints	1 Gallon = 1·2837 cft.
1 Imperial gln	1·2 American gln 1606 cft.
1 American gln	0·83 Imperial gln.
1 Cubic ft of water	6·24 gallons (British-Imperial)
1 Cwt of Water	1·8 cft = 11·2 glns.
1 ton of water	224 glns = 35·9 cft.

CONVERSION

Inches to centimetres	Multiply by	2·54
Centimetres to inches	,,	0·3937
Feet to metres	,,	0·3048
Metres to feet	,,	3·281
Yards to metres	,,	0·9144
Metres to yards	,,	1·094
Miles to kilometre	,,	1·609
Kilometres to miles	,,	0·6214
Sq. inches to sq cm	,,	6·452

6. Weights of Day-to-day Materials in use

1. Asbestos—Cement flat sheets	¼″ thick	2¼ lbs/sq ft.
,, corrugated ,,	,,	3½ lbs/sq ft.
2. Blast Stone Loose	1½″ (approx)	900 lbs/cft.
3. Bricks dry or Brick work		120 lbs/cft.
4. Cast Iron		450 lbs/cft.
5. Steel		490 lbs/cft.
6. Coal tar		650 lbs/cft.
7. Cement		100 lbs/cft.
8. Lime		112 lbs/cft.
9. Wire		555 lbs/cft.
10. Earth		95 lbs/cft.
11. Lead		707 lbs/cft.
12. Mortar		110 lbs/cft.
13. Glass	¼″ thick	3·5 lbs/sq ft.
	3/16″ thick	2·75 lbs/sq ft.

14. Paint ready made—	
(*a*) White Zinc	18 lbs/gallon.
(*b*) Chocolate	25 lbs/gallon.
(*c*) While lead	28 lbs/gallon.
(*d*) Aluminium or Bitumin	11 lbs/gallon.
15. Paper	55 lbs/cft.
16. Petrol	42 lbs/cft.
17. Cement plaster $\frac{1}{2}''$ thick	6 lbs/sq ft.
18. Lime plaster $\frac{1}{2}''$ thick	5 lbs/sq ft.
19. Sand, dry	98 lbs/cft.
20. Sand, wet	120 lbs/cft.
21. Steel, rolled	120 lbs/cft.
22. Tar	65 lbs/cft.
23. Tin	454 lbs/cft.
24. Turpentine oil, 1 gallon	82 pounds.
25. Water, one gallon	10 pounds.

7. Areas

(1) Area of a triangle $= \dfrac{\text{Base} \times \text{Altitude}}{2}$

(2) Equilateral $\triangle$ $= h = s\sqrt{\frac{3}{2}}$, $A = \sqrt{\frac{3}{4}} \times s^2$
(h=height—s=side—A=Area)

(3) Isosceles $\triangle$ $A = \dfrac{b}{4}\sqrt{4s^2 - b^2}$ (b=base)

(4) Circle $= \dfrac{\pi D^2}{4} = \pi r^2$ $\left(\pi = \dfrac{22}{7}\right)$

(5) Circumference of a circle $= \pi D = D \times 3{\cdot}1416$

(6) Side of an equal square $= D \times 0{\cdot}8802$

(7) Side of an inscribed square $= D \times 0{\cdot}7071$

(8) Rhombus $A = \frac{1}{2}\, d_1 \times d_2$ ($d_1 \times d_2$ are diagonals)

(9) Ellipse $A = \dfrac{\pi}{4} Dd$ (D=major axis)

(10) Parabola A=base $\times \frac{2}{3}$ height

(11) Trapezium A=Sum of Parallel sides $\times \dfrac{H}{2}$

(12) Volume and Surfaces=Diagonal of a cube=$a\sqrt{3}$
(a=edge of cube).

Simpson's Rule :

Area divided into equal parts each=d

$A=\frac{d}{3}$ [First ordinate+Last ordinate+2

(Total of ordinates)+4 (Total of even ordinates)]

8. Concrete

(1) **Lime Concrete** : 100 cft finished.

Brick ballast 1% ½″ stone 1½″	110 cft
Sand	34 cft
White lime	16 cft Kankar lime 40 cft

50 cft dry mixed mortar=38 cft of wet mortar.

Labour. Mason ¼, Labourers Male 2, Females 2.

For concrete over Jack arches 10% extra mortar used with metal of ½″ to ¾″ size.

Breaking brick metal 40 cft per day, one man.

Breaking brick stone metal 25 cft per day, one man.

(2) **Cement Concrete** :

1 cft of loose cement will make

4·3 cft	1 : 2 : 4	Concrete
5·0 cft	1 : 2½ : 5	,,
5·8 cft	1 : 3 : 6	,,
7·5 cft	1 : 4 : 8	,,

Please Note :

1. Ton of cement=20 bags.

2. 1 cft of cement weighs 90 to 94 lbs when loose filled. Weight of 1 : 2 : 4 concrete=100 lbs per cubic foot.

3. Average weight of 1 : 2 : 4 reinforced concrete 150 lbs per cubic foot

4. 1 cft of cement in paste will cover 9·5 sq ft 1″ thick.

5. 1 : 1 cement mortar (1 cement and 1 sand) will cover 16·8 sq ft 1″ thick.

6. 1 : 2 cement mortar (1 cement and 2 sand) will cover 29 sq ft 1″ thick.

7. 1 : 3 cement mortar (1 cement and 3 sand) will cover 35·5 sq ft 1″ thick.

8. 1 : 6 cement mortar (1 cement and six sand) will be equal for 500 bricks with $\frac{3}{8}$″ to $\frac{1}{2}$″ joints.

9. Natural river sand contains $\frac{1}{4}$ gm. to 1 gm. of water according to its condition of wetness.

(Coarser the aggregate, the less free water it will carry).

10. Aggregates absorb water :—

Sand	1·0% by weight
Lime stone	1·0% by weight
Sand stone	7·0% by weight

Very light and porous aggregate may be as high as 25% by weight.

11. Strength of cement concrete :—

(*i*) 28 days old	60%
(*ii*) 3 months	85%
(*iii*) 6 months	95%
(*iv*) 1 year	100%

12. Strength of Rapid Hardening Cement concrete :—

(*i*) 3 days	3853 lbs/sq in
(*ii*) 7 days	5360 lbs/sq in
(*iii*) 28 days	6810 lbs/sq in

13. Wind pressure on flat vertical surface :—

(*a*) $P=0{\cdot}0032\ V^2$ P=Pressure per sq ft.
V=Velocity of wind in miles per hour.

P=32 lbs/sq ft when V=100
P=40 lbs/sq ft when V=112

(*b*) On sloping roofs and surfaces :—
Dutchmin's formula

$$N=\frac{2 \sin Q}{1+\sin 2Q}$$

14. Rankine's formula

$$n = \frac{W}{P}\left(\frac{1-\sin Q}{1+\sin Q}\right)^2$$

P = Safe pressure on foundation in pounds per sq ft
n = Minimum Depth of foundation below G.L. (in feet)
W = Weight of earth in pounds/cft
Q = Angle of repose of ground material

15. Quantities of materials required for mortar and concrete :—

(*i*) 1 cft of cement plus 0·36 cft (2·25 gals) of water gives 0·835 cft of net cement mortar.
(*ii*) Brick work masonry needs 30 cft of mortar/100 cft.
(*iii*) Rubble masonry needs 50 cft of mortar/100 cft.

9. Safe Loads for Foundations

(*i*) Soft soil including marshy	$\frac{1}{4}$ tons/sq ft
(*ii*) Black cotton or made up soil	$\frac{1}{4}$ tons/sq ft
(*iii*) Sandy soil or made up soil	$\frac{3}{4}$ to 1 ton/sq ft
(*iv*) Shale	6 to 8 tons/sq ft
(*v*) Ordinary rocky	3 tons/sq ft
(*vi*) Moorum soil soft	2 tons/sq ft
(*vii*) Moorum hard	4 tons/sq ft
(*viii*) Piling	$1\frac{3}{4}$ ton for sq ft

Do not make mistake by—

(1) Using too much or too little water.
(2) Using old concrete.
(3) Using concrete on dry surface. Before placing saturate with water.
(4) Using dirty aggregate or dirty water.
(5) Repairing or levelling the concrete which has set or is exposed to sun and heat, without taking proper precautions to protect it and keep it damp.

CARES

(*i*) Calculate exactly how much finished concrete will be required for your job.

(*ii*) Ascertain how much cement-sand aggregate you require. Choose good materials and wash aggregate and screen sand before use.

(*iii*) Measure by measuring boxes only.

(*iv*) Do not mix in large batches at a time.

(*v*) Mix properly and use within 20 minutes.

(*vi*) Tamp it well and spade the edges.

(*vii*) Use proper centering materials and do not remove until the concrete is hard.

10. Fineness Modulus

The fineness modulus of an aggregate is obtained by adding the percentage by weight of materials retained on a range on nine selected sieves and dividing the result by 100 as per table.

S. No.	B.S. Sieve No.	Total percentage retained by weight	
		Sand	Aggregate
1.	100	100	400
2.	52	80	100
3.	25	60	100
4.	14	40	100
5.	7	20	100
6.	3/16″	0	100
7.	3/8″	0	80
8.	3/4″	0	50
9.	1½″	0	0

The practical limit of fineness Modulus for aggregate are for fine aggregate. From 2 to 3-5 for coarse aggregate for 5-5 to 8 and for mixed aggregate from 4 to 7. The maximum permissible volumes of fineness modulus of combined aggregates for mixes of various proportions are given in table below.

$$\text{Fineness Modulus} = \frac{\text{Sum of percentage}}{100} \quad \frac{300}{100} \quad 300 \quad \frac{730}{100 - 7{\cdot}3}$$

Cubic ft of combined aggregate to one Cwt of cement	Fineness of Modulus	
	Aggregate $\frac{3}{4}''$	Aggregate $1\frac{1}{2}''$
4	5·1	5·8
5	4·9	5·6
6	4 8	5·5
7	4·7	5·4
8	4·6	5 3
9	4·5	5 2

If P = Percentage of materials,
A = Fineness of Modulus,
B = Maximum permissible Fineness Modulus for combined aggregate from table,
C = Fineness of Modulus of Fine aggregate,

Then $$P = \frac{(A-B)}{(A-C)}$$

11. Earth Work and Excavation

One labourer excavates 100 cft to 150 cft of ordinary soil including dressing, with 5 ft lift and 100 ft lead.

Soft Moorum	75 cft
Hard Moorum	35 cft
Soft rock	20 cft
Hard rock	10 cft

including 5 ft lift and 100 ft lead.

Earth dug from pits increases in bulk by about 25%, sand, gravel, moorum 15%.

Following allowances may be made in shrinkage of earth work :—

Compact earth filling	1″ to 1½″ per ft height.
Loose earth filling	1½″ to 2″ per ft height.
Black cotton soil	2″ to 3″ per ft height.

12. Quantities required for various mixes for 100 cft concrete and mortar :—

Mix	Cement in Cwt for Aggregate	Dry sand
1 : 2 : 3	21·00	52·0
1 : 2 : 4	17·00	45·0
1 : 3 : 6	11·50	47·0
1 : 4 : 8	8·75	48·5
1 : 5 : 10	7·00	49·0

Note :—Add 5% for wastage of sand. Cement should be by weight. If hand mix, add 10% more cement.

13. Chemical Composition of Cement.

			Min.		Max.
Soluble silica (SiO_2)	22·0%	variation	12	and	37%
Insoluble silica	1·0 ,,				
Alumina (Al_2O_3)	7·5 ,,	,,	5	,,	10 ,,
Ferric oxide (Fe_2O_3)	3·5 ,,	,,	0	,,	7 ,,
Lime (CaO)	62·5 ,,	,,	58	,,	67 ,,
Magnesia MgO)	1·0 ,,	,,	0	,,	3 ,,
Sulphuric anhydride (SO_3)	1·0 ,,	—	—		—
Loss on ignition (CO_2)	0·5 ,,	—	—		—
(H_2O)	0·5 ,,	—	—		—
Alkalies and Loss (K_2O) (Na_2O)	0·5 ,,	,,	0	,,	·2 ,,
Total	100·0				

CHAPTER II

R.C.C. AND MASONRY

1. Reinforced Concrete

1 **General Rule.** Take about 4 lbs of reinforcement round bars per cft of concrete, where only simple tensile bars are used. This will be nearly 7 lbs per cft, where stirrups transverse and shear reinforcement are also included. In estimating the quantity of mild steel rods add an allowance for hooked ends as under.

Diameter of Rod :	¼″	3/8″	1/2″	5/8″	3/4″	7/8″	1″	1¼″	1½″
Allowance :	5″	7″	10″	12″	14″	16″	18″	22″	25″

Add for extra about ½ mason for reinforcement work per 100 cft of concrete. Add cost of soft iron binding wire, not less than 18″ gauge at the rate of lb/cwt of steel.

Labour for cutting, bending and binding rod :—

¼″ to ⅜″ dia rods 2½ cwt, one blacksmith per day.

½″ dia, one blacksmith per day for 3 cwt.

5/8″ dia and above 4 cwt, one blacksmith per day.

Total Labour for 100 cft of slab will be approx : Mason 2, Carpenter ½, Blacksmith 1½, Labour male 3 female 7.

2. Brick Work

(*a*) Brick work in lime	1 : 2 or 1 : 3	Labour :—	
Bricks 9″ standard	1400	Mason	2½
Mortar dry	33 to 40 cft.	Labour	4
Lime	25 cft.	(Two male and female)	Two

(*b*) Honeycomb brick work requires about 2 cft of mortar and half labour per 100 cft.

(*c*) Archwork requires double the labour of simple work.

Brick work in Cement :—

Quantity of cement required per 100 cft in cwts with cement sand mortar.

1 : 2	1 : 3	1 : 4	1 : 5	1 : 6
8·0	6·3	5·0	3·8	3·2

Add 10% for wastage.

Labour—2 masons and 4 labourers.

3. Reinforced Brick work

With cement mortar 1 : 3 in joints (Roof slab) :

Materials		
Bricks 9″	900 Nos.	Labour :—
Cement	18 cft.	Mason 3.
Sand	54 cft.	Labourers 5.
Steel (about)	5 cwt.	

With cement concrete 1 : 2 : 4 in joints and 1½″ on top of slab, per 100 cft of work (based on 6″ thick slab) :—

Bricks 500 Nos.

Cement concrete 70 cft + steel and forms

4. Stone Masonry

Materials :—

Uncoursed rubble masonry :

120 cft of stones and 33 cft of wet mortar.

Coursed rubble masonry :

130 cft stone and 25 cft wet mortar.

Ashlar

110 cft stones and 10 cft mortar.

Labour : Mason 1, Labourer 1½.

Dry stone masonry	50 cft per day.
Uncoursed rubble	30 cft per day.
Coursed rubble 1st Class	12 cft per day.
Coursed rubble 2nd Class	18 cft per day.
Coursed rubble 3rd Class	25 cft per day.

5. Cement concrete floors

1 : 2 : 4, ½″ thick 100 sq ft :—

(*a*) Materials :—

Cement	2·8 cft/2·25 cwt.	Labour :—
Sand	5·5 cft.	Mason ½
Small metal	1/8″ to ½″ 11·0 cft.	Labour ½.

Floors are laid in rectangles of 8 ft square.

(*b*) 1 : 3 : 6, 1½″ thick floor with ½″ thick wearing surface on top of fine 1 : 2.

Metal for 1½″ thick bottom layer size 1/8″ to ¾″ 12 cft.

Sand	6 cft.
Cement	2 cft.

Top layers

Fine Metal ¼″ grit	4 cft.
Cement	2 cft.

(*c*) For marble chips flooring or Mozaic flooring ¼″ thick top we need :

Chips 1/8″ grit	2 cft
Coloured cement	1 cft

(*d*) For red oxide colour flooring top ¼″ layer we need about 10 lbs red oxide per cft of loose cement.

Weight of colouring pigment used in excess of 10% of weight of cement reduces the strength of mortar. Where strength will not matter a max. proportion of 1 colouring pigment to 3 of cement can be used and the proportion should not be less than 1 : 12.

Note. **Do not use Steel Bars or Iron on Coloured Floors**

Carborundum stone is used for polishing the floor. 1 part of bees wax, 3 parts of turpentine are well rubbed over the floor for high class of polishing.

6 oz bees wax, 1 pint turpentine and 4 oz pigment.

Add : 10% to sand and aggregate for wastage.

6. Brick Floors

Per 100 sft :—

(*i*) Flat 3″ thick with pointing

Bricks 356 nos. (without wastage)

Mortar 9 cft.

Labour : Mason $\frac{1}{2}$ or $\frac{3}{4}$ Labourers 2

(*ii*) On Edge—4½" thick with pointing :

Bricks 450 nos. (without wastage)

Mason 1 Labourers 2 Mortar 13 cft.

(*iii*) Flat brick flooring—jointing the cement mortar 1 : 6 and flush pointing in cement mortar 1 : 3.

Quantity of cement=1 cwt per 100 sq. ft.

7. Pointing

(*a*) Cement required for 1000 sq. ft. of Flush pointing :

	1 : 1	1 : 2	1 : 3	Labour
Cement	8·2	5·0	3·8	Mason 3
ı	16·5	10·0	11·4	Bhistee 1 Labourers 4

For ruled pointing 75% extra mortar and labour. This includes raking out joints and curing.

For stone walls mortar will be 50% more and 1/3% more labour.

Requirement of mortar and labour for floors will be 1/6th less than walls.

Fine screened sand should be used for pointing.

8. Lime Pointing

Mortar required is about 20 cft dry or 15 cft wet per 1000 sq. ft. of pointing. Proportion may be—

(*a*) 1 lime+1 surkhi

(*b*) 1 lime+1 surkhi+1 sand

(*c*) 1 cement+1 lime+3 sand

(*d*) 1 cement+1 lime+1 surkhi+4 sand.

9. Plastering

(*a*) Mud plaster 1″ thick per 100 sq. ft.

Mud 10 cft. Labour : Mason ½

Bhusa or straw 1 cft. Labourer 2.

(*b*) Lime plaster :

½″ thick per 100 sq ft

Materials		Labour :
Lime, surkhi, sand etc.	6 cft.	Mason ½ Rough work.
or kankar lime,	5 cft.	Mason 1 Fine work.
Chopped jute or hemp	4 oz	Labour 2 and Bhistee ½

(*c*) **Lime, cement, and Surkhi plaster.** ½″ thick.

1 lime+1 cement+1 surkhi and seven sand.
This is equal to 1 : 5 cement plaster in strength.

(*d*) **Cement Plaster.**

Quantities of cement required per 100 sq. ft.

	1 : 2	1 : 3	1 : 4	1 : 5	1 : 6
3/8″	1·4	1·1	0·8	0·7	0·6
½″	1·6	1·3	1·0	0·8	0 6
¾″	2 4	1·9	1·4	1·1	0·8
1″	3·3	2·6	2·0	1·4	

10. Rubbing

Rubbing is a sort of thin plaster covering the surface of masonry. This is done by applying mortar and rubbing with rough surface of brick. This has proved successful where bricks are of inferior quality and is better than pointing.

Following proportions are used in rubbing :—

Lime Rubbing : 1 lime+1 surkhi+3 sand.

1 Cement+1 lime+surkhi+5 sand.

1 Cement+3 sand

1 Cement+5 sand.

After proper finish it gives an appearance of rough plaster.
Before operation, joints should be properly raked out.

11. White washing or colour washing. 100 sft. surface

(*a*) One coat 3 lbs white lime.
Two coats 5 lbs white lime.
Three coats 7 lbs white lime.
Gum 1 oz. to 15 lbs of lime is used.
Rice water can also be used.

For colour 2 oz less or more may be used as per taste to 15 lbs. of lime.

Labour : One trained man can do 1500 sq. ft one coat.

Rain water marks can be removed by applying thick ixture of tamarind and water and left to dry and then rubbed f. (Also bleaching powder with water is applied in case of is marks).

Note :—The doors, windows and ventilation of the rooms ould be closed before white wash or colour wash to avoid ferent shades caused by atmosphere, and outside heat.

(*b*) Cement washing : One man will do 500 sq. ft 2 coats in e day.

(*c*) Distempering :—100 sq. ft. surface.

1st coat	$2\frac{1}{2}$ lbs.
2nd coat	$1\frac{1}{2}$ lbs.

Cost of labour will be about 3 times that of white washing colour washing.

12. Wood work.

(*a*) 2″ thick panelled and glazed doors with chaukhats ames) 4′×7′ size.

Wood 5·8 cft. including waste.

Labour :—Carpenter 4, glazier 1/8, labourer 2. If the door wholly panelled it will need 103 cft of extra wood.

(*b*) $1\frac{1}{2}$″ thick panelled and glazed door with frames :—
4′×7′ wood 5 cft. (with wastage)

(*c*) $1\frac{1}{2}$″ thick panelled without chaukhats or frames
4′×7′=wood 2·70 cft. (with wastage)

(*d*) $1\frac{1}{2}''$ thick panelled doors of $4' \times 7'$ with wire gauze including frames $6\frac{1}{2}' \times 4'$: wood=4 cft.
wire gauze=13 sq. ft.

(*e*) 2″ thick panelled shutters $4' \times 6\frac{1}{2}'$
wood=2 70 cft.

(*f*) $1\frac{1}{4}''$ thick battened with 1″ braces, complete with haukhats $6\frac{1}{2}' \times 3\frac{1}{2}'$: wood=5·5 cft. Labour : carpenter 1, laourer 1

(*g*) $1\frac{1}{2}''$ thick venetian doors and windows.
Wood about 18 cft. per 100 sq. ft area.

(*h*) $1\frac{1}{2}''$ thick glazed windows $4' \times 5'$ with frames.
Wood 3·4 cft. Labour : carpenter 3
Labourers 2
Glazer $\frac{1}{4}$

(*i*) Jafri or trellis work per 100 sq.
Wood 7 cft : Labour : carpenter 2
Labourers 2

(*j*) Framing Labour 3 cft. one man per day.

(*k*) Joinery (hard wood) $1\frac{1}{2}$ cft. one man per day.

13. Painting.

(*a*) Ready made mixed paints : per 100 sq. ft on wood work.—

	New work	Old work
1st coat	2·8 lbs	1·9 lbs.
2nd coat	1·8 lbs	1·8 lbs.
3rd coat	1·7 lbs	1·7 lbs.

Red oxide paints for iron work will be 2·5 lbs for 1st coat, 1·8 lbs for 2nd coat.

(*b*) Painting iron work according to Railways.

ıts. Redlead.	Red Oxide	Double boiled Linseed oil	Raw Linseed oil	Lamp Black.

st Coat	28 lbs	2/3 glns	1/3 glns	—
nd Coat	12 lbs	do.	do.	½ lb.

Covering capacity of above : 1st coat 1200 sq ft
2nd coat 1300 sq ft

Labour : One painter will do 500 to 700 sq ft of surface of ood work.

1000 sq ft of iron work.—

Superior doors and windows only 200 sq ft per day.

Add 1/15th as cast of brushes and other sundries.

(*c*) Enamel paints : will cover 55 sq ft with 1 lb of paint.

(*d*) Measurements of painting of doors and windows are taken as :—

(*i*)	Panel or batten	2 times one side.
(*ii*)	Panel and venetian	2 times one side.
(*iii*)	Panel with glazed top	2 times one side.
(*iv*)	Iron barred doors	1½ times one side.
(*v*)	Iron barred with batten and sheets	3½ times one side.
(*vi*)	Battened window with iron bars.	2½ times one side.
(*vii*)	Venetian windows	2½ times one side.
(*viii*)	Venetian window with bars	4 times one side.
(*ix*)	Venetian window with bars glazed top	4½ times one side.
(*x*)	Venetian with bars and glass shutters	5 times one side.
(*xi*)	Glazed windows with iron bars	2 times one side.
(*xii*)	Glazed windows without bars	1½ times one side.
(*xiii*)	Glazed shutter	1 time one side.
(*xiv*)	Wire gauzed	1 time one side.
(*xv*)	Grated	¾ time one side.
(*xvi*)	Trellis work	2 times one side.

(*e*) Percentage addition for painting roof.—

Plain	Painted before erection	16%
	Painted after erection	12%

orrugated { Painted before erection 30%
Painted after erection 25%

(*f*) *Varnishing* :— One gallon will cover about 125 sq ft new surface, three coats, or about 700 sq ft old surface one coat).

(*g*) *Oiling* :— One gallon will cover about 800 sq ft one oat and about 500 sq ft of two coats.

(*h*) Coal tarring. Work 100 sq ft

One coat 5 lbs
Two coats 8 lbs
} add cost of kerosene oil etc.

(*i*) Solignum painting 100 sq ft
One coat 1/5 gln.
Two coats 1/3 gln.

(*j*) Bitumen painting for roof surface or Damp proof course per 100 sq ft of surface.
25 lbs bitumen.
2 cft sand.

14. Jack Arch Roofing

Per 100 sq ft $4\frac{1}{2}''$ thick.
Bricks 550 Nos. Concrete for haunches. $\frac{3}{4}''$ metal 50 cft.

15. Roofing.

(*a*) Double Allahabad Tiles. Single.—

Flat	220 Nos	105 Nos.
Half Round	110 Nos	105 Nos.

Ridge flat 10 Nos ; Ridges elbow 5 Nos. ; Eaves 10s ; Ventilator 6 Nos. Add lime concrete 4 cft.

(*b*) Mangalore Tiles— Roof not be at a slope less than 1 in 3—and more than 1 in 2.

Each tile is $16'' \times 9\frac{1}{4}''$ covers $12\frac{1}{2}'' \times 8\frac{1}{4}''$
150 tiles cover 100 sq ft. 1000 tiles weigh $2\frac{1}{2}$ tons.
Each tile weighs $5\frac{5}{8}$ lbs when dry.

Tiles rest on battens 2″×1″ or 1¾″×1″ fixed 12½″ centre to centre, to upper surface of rafters—Battens not be less than 1″×1″ and parallel to eaves. 10″ centre to centre in case of king-post truss. End tiles should be fastened with 18 No. gauge wire through the holes provided for the purpose with battens. Mangalore tile has breaking strength of 2 cwt applied at centres.

(*c*) Corrugated Galvanized iron sheets (20 B. W. G.)

Sheets 8′×32″	6 No.	Labour :	
Limpet washers	1 lbs	Carpenter	1
		Smith	1
G. I. bolts and nuts	1½ lbs	Labourers	3
G. I. Screws	3 lbs		
G. I. hook bolts	3 lbs		

(*d*) Asbestos Cement Sheets.

	(*i*) "Big Six" Sheet :	(*ii*) Trafford Sheets :
Length : 5′, 6′, 7′, 8′, 9′, and 10′		5′, 6′, 7′, 8′, 9′, & 10′
Overall width	3′—5½″	3′—7 1/16″
Laid width	3′—3¾″	3′—4″
Cover efficiency	95·78%	92·89%
Purlin spacing 5′—6″ (Max)		·5′—6″ (Max)
Spacing of Rails, for side cladding	6′—6″ (Max)	·6′—6″ (Max)
Horizontal lap (for slopes not less than 211/2°)		·6″
Actual cover 10′ sheet as laid	31·47 sq ft	31·67 sq ft
100 sq ft laid area requires sheeting (on basis of 5% loss by end laps with 10′ sheets)	109·90 sqft	113·31 sq ft
On basis of 8·33% loss by end with 6′ sheets	113·33 sqft	116·64 sq ft
Weight of 100 sqft as laid (approx)	357 lbs	332 lbs.

Colour Natural Grey.

Depth of purlin not less than 3″.

To get Number of bolts calculate sheets in one horizontal course plus two extra, for trafford.

To get No. of bolts multiply sheets in one horizontal course by two for *Big Six* corrugated sheets.

Hooks used 5/16″ galvanised iron only.

Hole drilled 7/16″.

Bitumen washers must be used under G.I. washers.

Screw the nuts or screw lightly first and tighten when a dozen or more sheets are laid. Do not screw too tightly on purlins.

Length of ridge is 3′—8″.

Sheets are also with ventilator and Roof light.

CHAPTER III

1. Carriage of Materials

Materials	Load for bullock cart	Load per truck
(*i*) Bricks 9″	200 to 250 Nos	2000 Nos
(*ii*) Mangalore tiles	250 Nos	2500 Nos
(*iii*) Ridge tiles	150 Nos	1500 Nos
(*iv*) Broken stone	12 to 15 cft	125 cft
(*v*) Moorum	16 cft	150 cft
(*vi*) Earth	18 cft	150 cft
(*vii*) Gravel or Bajri	12 to 15 cft	125 cft
(*viii*) Lime kankar	12 cft	150 cft
(*ix*) Slaked lime	15 to 20 cft	150 cft
(*x*) Boulders and Rubble	10 cft	100 cft
(*xi*) Iron	12 cwt	6 tons

2. Air space for Buildings

Class of Building	Cubic space per head	Floor area per head sqft
1. Residential houses	300	25— 30
2. Dormitories	400—500	30— 40
3. Factories	250	20— 25
4. Schools	144	10— 20
5. Hospital wards	1000	80—100
6. Army barracks	600	50— 60
7. Stables	800—1000	80—100

Height of the building should be between 10—12 ft or more ; lofty rooms are cooler.

3. Area of Windows

Area of windows or ventilators should be 1/5th of floor area with 1/10th minimum or 1 sq ft of window space per 100—125 cft of room contents in dwelling houses, and 1 sq ft to 50—55 cft in hospitals or 2·5 sqft per head in living room. Ventilators should be as high as possible. The sills of windows should not be less than 2′—6″ above the room floor level.

4. Stair Cases

For design of a stair case average human stride is taken as 23″ ; pitch is $= \frac{\text{Rise}}{\text{Tread}}$.

2 Rise + Tread = 23″ or Rise × Tread = 66″.

Standard—Rise 7″, Tread 9″ ; Rise 6″, Tread 11″, for residential and public buildings respectively. Rise should be limited to between 5½″ to 7″ and tread 9″ to 12″. Heights of flights for public buildings should be limited to 8 ft or 12 steps without landing or turn. Head room not less than 7 ft.

Doglegged—The flights run in opposite direction.

Open newel—There is space between flights called a well.

Geometrical—Geometrical stairs have no newel posts, but hand rail continues without interruption and without angular turns.

There is a well between the flights.

4. Stone Steps

Each stone should rest 1½″ on that below it. Also should rest 8″ on the wall on either sides.

5. Table for Task Work for an Experienced Artisan or Labourer per day

S. No.	Items	Task
1.	Ashlar	3 cft
2.	Block in coarse	4 cft
3.	Course rubble first class and second class	15 cft
4.	Course rubble third class	25 cft
5.	Randum Rubble	10 cft

6.	Uncoursed Rubble	25 cft
7.	Dry stone masonry	35 cft
8.	Dry Rubble retaining wall	25 cft
9.	Brick work first class 14″ and above	18 cft
10.	Brick work second class above 9″ thickness	25 cft
	($\frac{3}{4}$th of these for 9″ brick wall)	
	($\frac{1}{2}$ of these for 4$\frac{1}{2}$″ brick wall)	
11.	Honeycomb brick work	25 cft
12.	Ashlar in Arches	25 cft
13.	Circular or Arch brick work	10 to 15 cft
14.	Pointing (stone work)	75 sqft
15.	Pointing (Brick work)	50 sqft
16.	Rubbing (Lime)	90 sqft
17.	Rubbing (Cement)	100 sqft
18.	Plaster (Cement $\frac{3}{4}$″ thick)	35 sqft
19.	Plaster (Cement $\frac{1}{2}$″ thick)	30 sqft
20.	1 : 1 : 1 : 8 (1 cement, 1 lime, 1 surkhi and 8 sand) $\frac{1}{2}$″ thick	45 sqft
21.	1 : 1 : 1 : 8 (1 cement, 1 lime, 1 surkhi and 8 sand) $\frac{3}{4}$ thick	50 sqft
22.	Plaster lime with surkhi	60 sqft
23.	Lime plaster	80 sqft
24.	Stone paving	5 sqft
25.	Brick on edge	50 sqft
26.	Flagged or Shahabad stone flooring	40 sqft
27.	Plank ceiling	50 sqft
28.	Cloth ceiling	35 sqft
29.	Fixing roof battens for mangalore tiles	100 sqft
30.	Fixing roof battens for country tiles	60 sqft
31.	Country double tiling	50 sqft
32.	Country single tiling	100 sqft
33.	Mangalore tile covering	100 sqft
34.	Fixing corrugated iron roof sheets	33 sqft

35.	Fixing Asbestos corrugated sheet roof	35 sqft
36.	Fixing Asbestos trafford sheets	40 sqft
37.	Fixing Mangalore ridge tiles	50 ft
38.	Fixing Allahabad tiles double	38 sqft
39.	Fixing Allahabad tiles single	75 sqft
40.	Fixing Allahabad tile ridges	60 rft
41.	Fixing Asbestos ridge sheets	100 rft
42.	Fixing Valley gutters	25 rft
43.	Door panelled $4' \times 7'$ with frame	10 days
44.	Door panelled glazed $4' \times 7'$ with frame	10 days
45.	Door plain planked $2\frac{1}{2}' \times 2\frac{1}{2}'$	4 days
46.	Door ventined $4' \times 7'$ with frame	12 days
47.	Door battened $4' \times 7'$ double flap	7 days
48.	Door battened $2\frac{1}{2} \times 6'$-3" single flap	5 days
49.	Window glazed $4' \times 5'$ with frame	6 days
50.	Windows with plank shutters $3' \times 4'$ with frame	3 days
51.	Windows glazed $4' \times 5'$ with frame and venetianed double shutters	14 days
52.	Teak wood work (framing)	2 cft
53.	Teak wood work (jointing)	1 cft
54.	Painting 3 coats	60 sqft
55.	Varnishing 2 coats	100 sqft
56.	Distempering 2 coats	200 sqft
57.	White washing 3 coats	400 sqft
58.	Trellis work with frame (hoop iron)	50 sqft
59.	Trellis work with frame (wood)	33 sqft
60.	Trellis work with frame (Expanded Metal)	50 sqft
61.	Excavation in black cotton soil, or ordinary soil (5 ft lift and 100 ft lead)	100 cft
62.	Excavation in soft moorrum	75 cft
63.	Excavation in hard soil or hard moorrum	50 cft

64.	Excavation in shell rock	35 cft
65.	Excavation in soft rock	25 cft
66.	Excavation in boulder moorrum rock	66 cft
67.	Excavation in hard rock, including removing stones to 50 ft distance	15 cft
68.	Breaking metal 1½″ according to quality of rock	10 to 25 cft
69.	Conveying metal by head 100 ft lead	110 cft
	200′ lead	85 cft
	300′ lead	65 cft
	500′ lead	50 cft
70.	Breaking metal ¾″ according to quality of rock	5 to 15 cft
71.	Breaking metal 3/8″ according to quality of rock	5 to 10 cft

6. Colouring by dipping

Bricks or tiles coloured this way are said to stand any amount of exposure to weather without losing colour and the surface resists the growth of moss exposed to damp atmosphere.

(*i*) **For dark red colour**

1½ pints of turpentine
1½ pints of linseed oil
¼ lb of litharge
½ oz of Indian red

(*ii*) **For blue colour**

1 pint of turpentine
1 pint of linseed oil
½ oz of lithrage
1 lb of French ultramax

(*iii*) **For black colour**

2 oz of litharge
6 oz of manganese
4 oz of linseed boiled oil
6 oz of turpentine

(*iv*) **For grey colour**

3 oz of white lead
1 oz of litharge
1 oz of manganese
2 oz of boiled linseed oil
4 oz of turpentine.

These colours can also be applied to walls, floors, roofs etc. already built. Before applying bricks or tiles should be

thoroughly cleaned to avoid shades, and the liquid is laid on hot with a brush.

7. List of Standard sections and sizes of rounds, square, flat and angle iron

(*i*) *Rounds, Square and flat iron.*

Rounds—3/16″, ¼″, 5/16″, 3/8″ and ½″
5/8″, to 2″ rising by eighth
2¼″ to 4″ rising by quarters
41/8″, 45/8″, 5¼″, 6¼″, 7¼ and 8¼″.

Squares—¼ to 1¾ inches rising by eighth.
2 to 4 inches rising by quarters.

Flat bars—½″ to 1″×1/8″—1″ to 4″×¼″—1″ to 6″×3/8″
1″ to 6″×½″—1″ to 6″×5/8″ (width advancing by 1/8″)
1½″ to 6″×¾″—1½″ to 6″×7/8″—1½″ to 6″×1″ (width advancing by 1½″)

Flat girder bars—6″ to 16″ wide, thickness ¼″, 3/8″ and ½″ in 30 ft length.

(*ii*) *Angle bars*—

(*a*) ¾″×¾″, 1″×1″, 1¼″×1¼″, thickness 1/8″.

(*b*) 1″×1″, 1¼″×1¼″, 1½″×1½″, 1¾″×1¾″, thickness 3/16″.

(*c*) 1″×1″, 1¼″×1¼″, 1½″×1½″, 1¾″×1¾″, 2″×2″, 2½″×2½″ and 3″×3″, thickness ¼″.

(*d*) 2″×2″, 2½×2½″, thickness 5/16″.

(*e*) 2″×2″, 2½″×2½″, 3″×3″, 3½″×3½″, 3½×2½″, 4″×3″, 4″×4″, 5″×3″, 6″×3″, 6″×4″, thickness 3/8″.

(*f*) 2½″×2½″, 3″×3″, 3½″×3½″, 4″×3″, 4″×4″, 5″×3″, 6″×3″ and 6″×4″, thickness ½″.

(*g*) 3″×3″, 4″×4″ and 5″×5″, thickness 5/8″.

Tees—

(*a*) 1¼″×1¼″, 1½″×1½″, 2″×2″ and 2½″×2½″, thickness ¼″.

(*b*) 2½″×2½″, 3″×3″, 3″×4″, 3½″×3½″, 4″×3″, 4″×4″, 5″×3″, 6″×3″ and 6″×4″, thickness 3/8″.

(*c*) 3″×3″, 3″×4″, 3½″×3½″, 4″×3″, 4″×4″, 5″×3″, 6″×3″. thickness ½″ (length 24, 25 and 30 ft).

(*iii*) *Sheets and Plates.*

Sheets—(*a*) 18 to 24 B.W.G. size 4′ × 2½′.

(*b*) 1/16″ and 1/8″ thick, 6, 8, 10 and 12′ long, 3′ and 4′ wide.

Plates—(*a*) 3/16″ to 5/8″ thick, 6, 8, 10′ long by 3′, 3½′ and 4′ wide.

(*b*) ¾″ to 1″ thick, 6 and 8 ft long, 3′ and 4′ wide.

8. Weight of Iron, when determined.

(*i*) Wrought iron 40 lbs/ft 1″ thick. (*ii*) Steel 40·81 lbs/ft 1″ thick. (*iii*) Cast iron 37·5 lbs/ft 1″ thick.

9. Cement looses strength if stored as below

1.	Fresh cement	100%
2.	After 3 months	80%
3.	After 6 months	75%
4.	After 1 year	70%
5.	After 1¼ years	65%
6.	After 1½ years	60%
7.	After 1¾ years	55%
8.	After 2 years	50%

Old cement should be added with additional cement according to above, when used.

10. Weight of Galvanised Sheets

Gauge No.	8	10	12	14	16
Wt. oz/sqft	112·5	92·5	72·5	52·5	42·5

CHAPTER I

(i) Minimum Thickness of Walls for Buildings for Residential Purposes

Height	Length of walls	Thickness
Up to 10 ft	Any Length	9″
10 to 15 ft	Any Length	14″ for height of 8′, 9″ for remaining.
15 to 25 ft	Up to 30 ft	14″ for whole height.
	Above 30 ft	18½″ for 10 ft height, 14″ for the rest.
25 to 30 ft	Up to 35 ft and above	18½″ for 10 ft & rest 14″.
30 to 40 ft	Up to 35	18½″ for 10 ft & rest 14″.
	Above 35 ft	23½″ for 10 ft, & rest 14″ & 9″ 10′ & 15′ respectively or Ground floor of 23½″, Second floor of 18½″ etc.
40 to 50 ft	Up to 35 ft	18″ below topmost floor 14″ for the rest.
	Above 35 ft	24″ for height of one story, 18½″ for rest of its height below topmost story and 14″ for the rest of height.
50 to 60 ft	Up to 40 ft	23½″ for the height of one story, 18½″ for the rest.

	Above 40 ft	$23\frac{1}{2}''$ for the height of two storys, $18\frac{1}{2}''$ for rest except top story, which may be 14″ or 9″.
	Above 50 ft	$28\frac{1}{2}''$ for 1st story, $23\frac{1}{2}''$ for next two, $18\frac{1}{2}''$ for remaining height, except top which may be 14″.
60 to 70 ft	40 ft length	$23\frac{1}{2}''$ for two storys, $18\frac{1}{2}''$ for remaining height, except top which may be 14″.
	Above 40 ft	$28\frac{1}{2}''$ first, $23\frac{1}{2}''$ second, $18\frac{1}{2}''$ rest of storys except top which may be 14″.

Minimum Thickness of Walls for Public Buildings and Ware Houses

Height.	Length	Thickness at base	Remarks
15′	Unlimited	14″	In any wall over 25′ height, uppermost 15′ to be less than 14″ thick. The remainder of the walls below uppermost 15′, shall not be less in thickness than the space contained between two straight lines drawn from each outside of wall at its base, to each other side of wall 15′ below top. Cross walls to be at least two-thirds of external walls subject to a minimum of 9″.
15′—25′	Do.	$18\frac{1}{2}''$	
25′—30′	Upto 45′	$18\frac{1}{2}''$	
	Above 45	$23\frac{1}{2}''$	
30′—40′	Upto 30′	$18\frac{1}{2}''$	
	30′ to 60′	$23\frac{1}{2}''$	
	Above 60′	$28\frac{1}{2}''$	
40′—50′	Upto 40′	$23\frac{1}{2}''$	
	40′ to 70′	$28\frac{1}{2}''$	
	Above 70′	$33\frac{1}{2}''$	
50′—60′	Upto 35′	$23\frac{1}{2}''$	
	35′ to 50′	$28\frac{1}{2}''$	
	Above 50′	$33\frac{1}{2}''$	
60′—70′	Upto 30′	$23\frac{1}{2}''$	
	30′ to 45′	$28\frac{1}{2}''$	
	bove 45′	$33\frac{1}{2}''$	

3. Terrazzo Finish.

Ordinary terrazzo is a concrete with a marble chippings agg regate, with a surface ground to smooth finish. The marble chippings may be of any colour required and are obtained in the grades 3/32″, $\frac{1}{8}$″, $\frac{1}{4}$″, 3/8″ and $\frac{1}{2}$″. The cement should be ordinary grey cement or white or as per required colour.

Proportion : 3/32″ ... 1 : 2$\frac{1}{2}$ chippings.

$\frac{1}{8}$″ and $\frac{1}{4}$″ ... 1 : 3 ,,

3/8″ and $\frac{1}{2}$″ ... 1 : 2$\frac{1}{2}$,,

$\frac{1}{8}$″ to $\frac{1}{2}$ ... 1 : 3 ,,

On no account mixture to be richer than 1 : 3.

4. Coloured Terrazzo Flooring.

Colour	Chippings	Materials
(*i*) Red	2 parts $\frac{1}{4}$″ dark red 1 part $\frac{1}{8}$″ ,, ,, 1 part $\frac{1}{4}$″ ,, ,, 1 part $\frac{1}{8}$″ pink	1 cement, red oxide 1/12th of cement (in weight)
(*ii*) Pink	1 part 3/8″ pink 1 part $\frac{1}{4}$″ ,, 1 part $\frac{1}{8}$″ ,,	1 cement, with 1/12th red oxide of cement by weight.
(*iii*) White in Red	1 part each $\frac{1}{8}$″, $\frac{1}{4}$″ and 3/8″ each white	1 cement, 1/10th of oxide, by weight 1/75th of blue ultramarine by weight.
(*iv*) White in Black	1 part each $\frac{1}{4}$″, 3/8″ and $\frac{1}{2}$″ white	1 cement, with 1/8 part black manganese
(*v*) White and Black (Speckled).	$\frac{1}{2}$ part of each $\frac{1}{8}$″, $\frac{1}{4}$″ and 3/8″ white $\frac{1}{2}$ part each of $\frac{1}{8}$″, $\frac{1}{4}$″ and 3/8″ black	1 cement, 1/2 part white
(*vi*) Black in Green	1 part each 3/8″, $\frac{1}{4}$″, 3/8″ and $\frac{1}{2}$″ green	1$\frac{1}{2}$/parts cement mixed with 1/6th part chromium oxide by weight.

(*ii*) Corrugated Galvanized iron, Asbestos Sheets ¼ to 1/6 span.

11. Minimum size of structures.

Size	Length	Breadth	Height
(*i*) Motor Garage or Tonga House, Doorway 8′	18′	12′	9′
(*ii*) Motor Pit. (Covered wi.h 1½″ planks Ramp slope 1 in 8 to 1 in 10)	12′	2′—9″	4′

(*iii*) Coal Store, for each ton ; 45 cft. Doors to open outwards.

(*iv*) Cattle shed open in front. 100 sq. ft. including verandah

Stall 5′ to 6′ 10′×10′×12′.

For each Goat or Sheep 10 sq. ft.

Cow, Buffalo, Bullock 50 sq. ft.

(*v*) Residential :—

No living room less than 120 sq. ft.

No kitchen less than 90 sq. ft.

No bath room less than 25 sq. ft.

No W. C. less than 12 sq. ft.

No latrine less than 16 sq. ft.

12. Foundation in Black Cotton Soil.

I. Foundation load is limited to 1000 lbs per sq. ft. if water finds access to the foundations, otherwise it may be about 1 ton per sq. ft.

II. Foundations are taken down to such depths to which the cracks do not extend.

III, Trenches are dug on either side of the foundations and filled with sand or other loose materials to prevent intimate contact of black cotton soil with foundation work.

IV. Foundation concrete is laid over 18″ layer of sand or any other loose material to avoid contact of black cotton soil with concrete.

V. If the thickness of black cotton soil is 3′ to 4′ it should be completely removed and foundations laid on the soil blow.

VI. For important buildings Raft foundations of reinforced concrete are provided.

Method: (*i*) Bottom of trenches is well watered and rammed with heavy rammers, and then 12″ layer of hard moorum is laid and is well watered and rammed. Over the 12″ layer of boulders and moorum are laid and well rammed and consolidated by water. On this 18″ layer of sand or loose material is laid. To avoid the sand being spread in haphazard way and going in the cracks of soil, thin layer of masonry is built alround in mud mortar. On the top of sand, concrete is laid. The masonry of foundations should be at least 6″ below natural ground level. The sides of this masonry should be packed with sand up to ground level.

(*ii*) Trenches are excavated to a depth of 5′ to 6′ width greater than the width of bottom of footings, by 1½ ft. Cement concrete is filled in to a thickness of 9″ on each side, thus leaving a space equal to the width of the bottom of the masonry and 9″ high which is filled with sand. On top of this (for full width of trenches) R. C. C. slab is built 6″ thick. Masonry (Foundation footings) is built upon R. C. C. slab and 9″ space left on both sides of the foundation masonry filled with sand. A vertical pipe 3″ dia is passed through the plinth masonry down to sand under the R. C. C. slab (through the masonry and the slab) which is kept filled with sand. The sand in tube will fill up the hollow created at bottom. Such tubes can be built from 4′ to 5′ apart and inspected at every change of season and filled with sand if required.

(*iii*) In case where black cotton soil is encountered and good foundation is at greater depth than 4′ below surface, is put in shallow foundations and use two reinforced concrete courses of bands, each 4″ thick—one at plinth level and the other at lintel level over doors and windows. Where second band acts as lintel it should be adequately reinforced. This prevents cracking masonry, which might be caused by wet and dry weather. In addition to this for costly buildings, raft foundation is also used.

13. Piles. Safe bearing of piles.

Wei ht of Monkey	Fall of Monkey	Penetration with belows
8 cwt.	5 ft.	1/5″ in 30 belows.
15 cwt.	15 ft.	1/4″ in 10 belows.
8 cwt.	30 ft.	1/5″ in 10 belows.

Pile load limited to 50 tons for R.C.C Piles and 20 tons for timber piles. Spacing of piles, min. 3′—6″.

14. Safe load for Precast Reinforced concrete piles.

Size	Max. Load in tons	Wt. of pile shoe	Max. Length in ft.	Dia. 20′	30′	40′	50′	60′	70′	
12×12	35—40	30	40	¾	7/8	1	—	—	—	—
14×14	50—55	40	55	¾	7/8	1	1⅛	—	—	—
16×16	65—75	50	65	—	7/8	1	—	1⅛	1¼	—
18×18	80—90	60	75	—	—	1	—	1⅛	1¼	1⅜

15. Safe loads in tons of Timber Piles and Struts.

Length in ft.	Size				
	4″	6″	9″	12″	15″
6	5·3	13·8	33·5	61·5	97·7
10	4·0	11·5	30·3	57·6	93·2
20		7·5	22·0	45·9	79·0
30			16·2	36 2	64·9
40				28·8	53 8
50				23·6	45 2

Piles should not be loaded above 15 to 20 tons except for bridges.

16. Safe load permissible.

(*i*)	Cement concrete	1 : 2 : 4 ... 30	Ton/sqft.
(*ii*)	,, ,,	1 : 3 : 6 ... 20	,,
(*iii*)	,, ,,	1 : 4 : 8 ... 10	,,
(*iv*)	Mortar	1 : 6 ... 20	,,
(*v*)	,,	1 : 8 ... 15	,,
(*vi*)	,,	1 : 10 ... 10	,,
(*vii*)	Lime Concrete	... 5	,,
(*viii*)	Brick work in cement	1 : 3 ... 12	,,

(*ix*)	Brick work in cement	1 : 4 ...	10	Ton sqft.
(*x*)	,, ,, ,, lime	...	5	,,
(*xi*)	,, ,, ,, mud	...	3	,,
(*xii*)	Sun-dried brick work	...	1	,,
(*xiii*)	Stone masonry in cement	1 : 3 ...	15	,,
(*xiv*)	,, ,, ,, lime	...	8	,,

17. Thickness of Arches (semi-circular and segmental)

		Thickness of arch ring	
Span upto 5 ft.	...	9″	
,, 6′—14′	...	13½″	
,, 15′—25′	...	18″	
,, 20′—35′	...	22½″	
,, 36′—50′	...	27″	Brick in cement mortar 1 : 4

18. Retaining wall Average Angle of Repose.

	Soil	*Angle of repose*
(*i*)	Wet clay : Wet sand and clay or wet gravel and clay (soils not properly drained)	20°
(*ii*)	Dry clay : wet sand : gravel	27°
(*iii*)	Dry sand : loose earth, dry or wet, damp	

		Angle of repose
	clay gravel, sand and clay ; common soils (properly drained)	33°
(*iv*)	Sand and clay ; gravel and sand	37°

19. Domestic chimneys and Fire-places.

Sizes of Flues in general use :—

9″×9″ —For small grates.
14″×9″ }
16″×9″ } —For ordinary domestic Fire place
14″×14″ —For long kitchen sizes.

20. Lintels.

(*i*) Stone lintels—

Drafts = 1″ for each foot of spare +1″

(*ii*) R.C. lintels—

$$H = 0{\cdot}318L\frac{3}{2}$$

where H=effective depth of lintel in inches.

L=effective span in feet.

For small spans and ordinary loads, take 6″ depth for 4 ft. span and add 1″ for each foot of span.

21. Reinforcement for 4½″ brick wall.

1 bar 3/8″ dia. for spans under 4 ft.

1 bar ½″ dia. for spans 4 ft. to 7 ft.

1 bar 5/8″ dia. for spans 7 ft. to 10 ft.

CHAPTER VII

Reinforced Cement Concrete and Structural Engineering

The use of reinforced concrete in structural engineering and buildings is on the increase in these days.

1. General principles of design.

(*a*) Slabs are not less than 2½" overall thickness.

(*b*) Simply supported slabs should have an effective depth of not less than 1/20 of the spans. In case of slabs spanning in two directions it may be 1/30 of the span. Continuous slabs may have a thickness of 1/30 and semi-continuous 1/22 of the span.

(*c*) For cantilevers the effective depth near the support should not be less than 1/7·5 of the projection. This depth obviates deflection.

(*d*) In fixing cross sections of a beam, the effective depth is taken not less than the breadth and not more than three times the breadth.

(*e*) The unsupported length of a beam should not be more than 32 times the width of the beam for rectangular beams or width of the flange for T beam.

(*f*) For calculations, effective span is taken equal to clear span plus effective depth. Effective de pth is from top of concrete to centre of tensile steel.

(*g*) A good rule for the breadth of a rectangular beam or the breadth of the rib of a T-beam is to take 3/5th of the total depth of the beam.

(*h*) The top surface of the centering should be given a chamber of 1/12" for every foot of span, subject to a maximum of 1½" for beams, to allow for initial settlement.

2. Bending Moment Co-efficients.

Beam and slabs are generally designed for bending moment as (for distributed loads)—

(*i*) Simply supported $\frac{W}{8}$

(*ii*) Semi-continuous $\frac{WL}{10}$

(*iii*) Continuous or Fixed $\frac{WL}{24}$ or $\frac{WL}{12}$.

In case of a freely supported beam with B.M. of $\frac{WL}{8}$ at centre, reinforcement for a negative B. M. at top of not less than 1/3 of minimum positive reinforcement should be provided at the ends and similarly for semi-continuous slabs equal to $\frac{1}{2}$" of the positive reinforcement, or alternatively, $\frac{1}{3}$ or $\frac{1}{2}$ of the main bars should be bent up.

In case of fixed beams, bending moment is to be calculated over the supports and reinforcement provided accordingly.

3. Pitch.

Bars under no circumstances should be placed apart than 12" or twice the effective depth of slab, whichever is less. This may be increased to three times in two-way reinforced slab towards the ends. Spacing of transverse bars should not exceed 18" or four times the effective depth. The clear space between the bars should not be less than the diameter of the bars or $1\frac{1}{2}$ times the maximum size of the aggregate, whichever is more. Similarly the clear vertical space between the bars should be more than the maximum size of aggregate, or the base should be placed one above the other without any space in between.

4. Minimum size of Bars.

Columns	$\frac{1}{2}$" dia.
Beams and Slabs	$\frac{1}{4}$" dia.
Transverse reinforcement or tempt. bars, spiral, stirrups or secondary reinforcement	3/16" dia.

5. Add allowance for hooks in M.S. Bars.

Dia.	*Allowance*	
1/4″	5″	
3/8″	7″	
1/2″	10″	
5/8″	12″	
3/4″	14″	
7/8″	16″	
1″	18″	and so on.

6. Expansion joints.

In long span allow $1\frac{1}{2}''$, maximum, for expansion per 100 sq.ft. of length of the slab with $\frac{1}{4}''$ minimum, according to temperature changes.

7. Square iron rods.

Side of square bar in inches	Perimeter in inches	Section arc in sq. inches	Wt. in lbs. per rft.
1/4	1·00	0 625	0·213
3/8	1·50	0·1406	0·478
1/2	2·00	0·250	0·849
5/8	2·50	0·3806	1·328
3/4	3·00	0·5625	1·912
7/8	3·50	0·7656	2·603
1	4·00	1·000	3·400
1 1/8	4·50	1·266	4·303
1 1/4	5·00	1·5625	5·312
1 3/8	5·50	1·8906	6·428
1 1/2	6·00	2·250	7·650

$$\text{Spacing in } 12'' \text{ slabs} = \frac{\text{Area of bar} \times 12}{\text{Area of steel required}}.$$

8. Concrete cover outside or under steel.

(*i*) Slabs and walls	dia. of bar or $\frac{1}{2}''$ minimum.
(*ii*) Beams	dia. of bar or 1″ minimum (side, top, bottom) ; ends 2″
(*iii*) Piles	$1\frac{1}{2}''$ min. sides.
(*iv*) Water tank	$1\frac{1}{4}''$ with rich concrete. $1\frac{1}{2}''$ with 1 : 2 : 4
(*v*) Marine works	Twice ordinary structures.
(*vi*) Works exposed to—	
(*a*) Weather	$1\frac{1}{2}$ times ordinary structures
(*b*) Foundations	$1\frac{1}{2}''$

(All these coverings are beyond stirrups and binders).

9. Compacting concrete.

Concrete shall be thoroughly compacted during the operation of placing and thoroughly waked around the reinforcement, around embedded fixtures, and finished within half an hour of adding water to the mix, but in hot climate this period is reduced.

10. Covering Concrete.

Concrete should be protected from hardening, from sunshine, drying winds and colds. Also it needs protection from water and shocks, in first stage. The concrete shall be prevented from drying-out and moist conditions maintained for at least 14 days, under no circumstances less than 7 days ; in very important works 28 days.

11. Water Proofings.

(*i*) Making the concrete impermeable to the penetration of water. There is no agent which added to concrete prepared without care is capable of closing the passageways through which water penetrates. Therefore care should be taken (*a*) to use clean, graded sand or fine aggregate and clean water,

(*b*) preparing mix, with minimum amount of water, (*c*) mixing properly, (*d*) placing carefully, (*e*) avoiding as much air in mix as possible by rodding, puddling and by vibration of forms, (*f*) avoiding laitance at joints, by removing laitance and roughening it before putting another layer, (*g*) curing well and for longer periods.

(*ii*) After the above precautions are observed in certain cases *e.g.* in the case of water tanks, it may be advisable to take further steps to prevent water penetration. This may be done either by "integral" water proofing or by surface applications. In the first method various proprietary compounds, such as pudlo, Medussa, cresit, ironite etc., are incorporated with the cement or water for mixing. In certain cases the materials are added to the cement during manufacture.

All are deemed to have void filling and lubricating properties.

(*iii*) Soap solution acts as lubricants and also form insoluble Fillers by reaction with cement. They may be incorporated or applied as a coat while the concrete is yet green.

(*iv*) Lime soap with alum and hydrated lime in the form of a dry powder is also mixed with cement to attain the same object. The hydrated lime aids lubrication.

(*v*) As regards surface applications the method depends on the quality of the concrete. If the pores are very small, slit or fine clay may fill them, or a soap and alum mixture may be applied. For somewhat greater pores paraffin or bitumen or an asphaltic may be applied by brush. Bitumen may be used either as a solution or hot or incorporated in paints. The concrete surfaces to which bitumens are applied, should be thoroughly dry and preferably warm, at the time of application. The bitumen in solution, melted, or in paint, should be well rubbed into corners and recesses, and must form a continuous film.

(*vi*) Membranous water proofings are also employed sometimes, continuous sheets covering the surface, but this type is usually employed in water-proofing structures in course of erection, such as subways, tunnels etc.

(*vii*) Treatment of silicate soda is also recommended.

12. R. C.C. Lintel 9″ or 14″ wide and Cantilevers

Opening	Depth		Main Tensile Reinforcement Inches			
			Straight Bar		Cranked Bars	
Feet	Effectvie	Over all	No.	Size	No.	Size
		Lintels	*(1/4″ θ stirrrps and 3/4 of Depth*			
3 or 4	2½	3½	2	¼	1	¼
5 or 6	4	5	2	½	1	⅜
7 or 8	6	7	2	½	1	½
9 or 10	8	9	3	½	2	½
		Cantilevers (Bend Alternative Buttom bar)				
			Spacing		*Distribution Bars Spacing*	
3 or 4	3	4	4″	⅜	6″	¼
5 or 6	4	5	6″	½	9″	⅜
7 or 8	6	7	4″	½	6″	⅜

Note. Care should be taken not to use part of reinforcing in building for conducting electrical currents.

12. Resistance Moments of R.C.C. Slab.

Unit stress in concrete ... fc.=750 lb./sq. inch.

Unit stress in steel ... fc.= 18000 ,, ,, ,,

Co-efficient ... R=137 ,, ,, ,,

Percentage of steel ... P=·0089 ,, ,, ,,

Moment of Resistance ... MR=Rbd,

where effective depth d=total depth, t minus 1½″

,, breadth b=12″

Area of steel $As=Pbd$.

Slab Thickness in inches.	Effective Depth in inches	Moment of Resistance in in./lb. (M. R.)	Steel reqd in inches	Main steel bars proposed	As supplied	Description of Steel bars proposed	Wt. of slab per sq. ft. in. lbs.
7	5½	49400	0·59	5/8''@6'' c.c.	0·60	3/8'' @ 10'' c.c	84
7½	6	59200	0·64	5/8''@5½''c.c.	0·67	3/8'' @ 9½'' c.c.	90
8	6½	69500	0·70	5/8''@5'' c.c.	0·74	3/8'' @ 9'' c.c.	96
8½	7	80600	0·75	5/8''@5'' c.c.	0·74	3/8'' @ 9'' c.c.	102
9	7½	92500	0·80	5/8''@4½''c.c.	0·82	3/8'' @ 8'' c.c.	108
9½	8	105300	0·86	5/8''@4'' c.c.	0·92	3/8'' @ 7'' c.c.	114
10	8½	118000	0·91	5/8''@4'' c.c.	0·92	3/8'' @ 7'' c.c.	120
10½	9	133000	0·96	¾'' @ 5½''c.c.	0·96	½'' @ .2'' c,c.	126
11	9½	148000	1·01	¾'' @ 5'' c.c.	1·06	½'' @ 11'' c,c.	132
11½	10	164000	1·07	¾'' @ 5'' c.c.	1·06	½'' @ 11'' c.c.	138
12	10½	181000	1·12	¾'' @ 4½''c.c.	1·18	½'' @ 10'' c.c.	144
12½	11	199000	1·17	¾'' @ 4½''c.c.	1·18	½'' @ 10'' c.c.	150
13	11½	216000	1·22	¾'' @ 4'' c.c.	1·32	½'' @ 8½'' c.c.	156
13½	12	237000	1·28	¾'' @ 4'' c.c.	1·32	½'' @ 8½'' c.c.	162
14	12½	256000	1·33	¾'' @ 4'' c.c.	1 32	½'' @ 8½'' c.c.	1 8
14½	13	278000	1·44	7/8''@5'' c.c.	1·44	½'' @ 8'' c.c.	174
15	13½	298000	1·44	7/8''@5'' c.c.	1·44	½'' @ 8'' c.c.	180

13. Safe Loads for 1 : 2 : 4 Concrete Circular columns with l/d less 15.

Dia of columns outside.	Longitudinal reinforcement		Spiral reinforcement		Safe Load in 1000 lbs.
	No.	Dia.	Dia in. Pitch.	Pitch inches	
6	8	3/8	5/16	1¼	44
	8	1/2	5/16	1/8	59
	8	5/8	5/16	1	75
8	8	½	5/16	1¼	79
	8	5/8	5/16	1-1/8	76
	8	7/8	5/16	1	139
10	8	½	5/16	1¼	106
	8	¾	5/16	1-1/8	139
	8	1	5/16	1	184
12	8	½	5/16	1½	125
	8	7/8	5/16	1	198
	12	1	5/16	1¼	257
15	8	5/8	5/16	1¾	189
	8	1 1/8	1/2	2¼	267
	12	1½	5/8	2¼	437
18	8	5/8	5/16	1¾	232
	8	1-1/8	½	2¼	384
	12	1½	¾	2¼	648
21	8	5/8	5/16	1¼	129
	8	1-1/8	½	1¾	510
	12	1½	¾	2¾	800
24	8	7/8	5/16	1¾	375
	8	1½	½	1¾	636
	12	1½	¾	2½	909

14. Safe load 1 : 2 : 4 cement concrete.—

Square column with l/d less than 15 stress in steel=18000 *stress in concrete*−600.

Size of column on C	Core	Vertical rods round	Load in 1000 lbs.	Binders	
				Size	Spacing
6″×6″	4″×4″	4′—½″	35	16 s.w.a.	6″
8″×8″	6″×6″	4′—½″	52		,,
		4′—1″	99	10 s.w.a.	,,
10″×10″	8″×8″	4′—5/8″	81	,,	,,
		4′—11/8″	129	,,	,,
12″—12″	10½″×10½″	4′—¾″	117	,,	,,
		4′—5/8″	108	,,	,,
14″×14″	11″×11″	4′—7/8″	156	¼″ dia.	,,
		4′—¾″	148	,, ,,	,,
16″×16″	13″×13″	4′—¾″	208	,, ,,	,,
		4′—7/8″	196	,, ,,	,,
18″×18″	14″×14″	8′—¾″	256	,, ,,	,,
		4′—1″	249	,, ,,	,,
20″×20″	16″×16″	8′—7/8″	324	5/16″ ,,	,,
		8′—¾″	302	,, ,,	,,
22″×22″	18″×18″	8′—1″	400	,, ,,	,,
		8′—7/8″	374	,, ,,	,,
24″×24″	20″×20″	8′—1″	455	,, ,,	,,
		8′—7/8″	429	,, ,,	,,

15. For R.C.C. Water tank.

Ordinary 1 : 2 : 4 cement concrete does not make waterproof, therefore a rock mix making the concrete waterproof should be used. 1 : 1½ : 3 mix is quite suitable. But for very thick solution 1 : 2 : 4 mix is sufficient. As there will be tension in concrete, to avoid cracks, sufficient thickness of concrete should be provided. Steel also should not be stressed to the same limit as in other structures.

16. Internal Diameter of Circular Tank.—

$$\sqrt{\frac{\text{Capacity in gallons}}{4{\cdot}91\ \text{h.}}}$$

Dia in ft.	Capacity in gals. per ft. of ht.	Dia in ft.	Capacity in gals per ft. of ht.	Dia in ft.	Capacity in gals. per ft.
5	122	11	595	17	1420
6	176	12	730	18	1583
7	240	13	830	19	1770
8	314	14	953	20	1940
9	396	15	1100	25	3115
10	490	16	1247	30	4410

Table of Cement Mortar for Different Masonries and different items of work.

Work	Proportion	Per	Cement in feet.	No. of bags.
Brick work for Heavy works, such as bridges retaining walls etc.—				
(*i*) Foundation,	(*i*) 1 : 3	100 cft	25 cft	7¼
(*ii*) Superstructure	(*ii*) 1 : 5	100 ,,	25 ,,	4¼
Brick work for light Structures such as buildings for residential purpose schools etc.				
(*i*) Foundation	(*i*) 1 : 5	100 ,,	25 ,,	4¼
(*ii*) Superstructure	(*ii*) 1 : 8	100 ,,	25 ,,	2¾
Coarse rubble Heavy works.—				
(*i*) Foundation	(*i*) 1 : 3	100 ,,	30 ,,	8½
(*ii*) Superstructure	(*ii*) 1 : 5	100 ,,	30 ,,	5¼
Coarse rubble Light works.—				
(*i*) Foundation	(*i*) 1 : 5	100 ,,	30 ,,	5¼
(*ii*) Superstructure	(*ii*) 1 : 8	100 ,,	30 ,,	3¼
Cement plaster.—				
(*a*) ½" thick outside walls	(*a*) 1 : 4	100 ,,	5 ,,	1
(*b*) ½" thick inside walls	(*b*) 1 : 6	100 ,,	5 ,,	¾
(*c*) ½" thick on ceiling	(*c*) 1 : 3	100 ,,	3 ,,	¾

17. Small R. C. Tanks with 1 : 2 : 4 Concrete (Circular)

No.	Capacity	Size of Tank		Thickness of Concrete for walls & floors	Reinforcement		
					Walls		Floor.
		Inside Dia	Depth		Spacing of horizontal rods of bottom half depth. (Circular)	Spacing of vertical rods	Spacing of rods each way 3/8" bars.
1	2	3	4	5	6	7	8
1.	500	5'—6"	3'—6"	0'—4"	¼" @ 6" c.c.	¼" @ 8" c.c.	9" c.c.
2.	750	6'—6"	4'—0"	0'—4"	¼" @ 6" c.c.	¼" @ 8" c.c.	9" c.c.
3.	1000	7'—0"	4'—6"	0'—4½"	3/8" @ 9" c.c.	¼" @ 8" c.c.	8" c.c.
4.	1500	8'—0"	5'—0"	0'—4½"	3/8" @ 8" c.c.	¼" @ 6" c.c.	8" c.c.
5.	2000	9'—0"	5'—6"	0'—5"	3/8" @ 7" c.c.	¼" @ 6" c.c.	7" c.c.
6.	3000	10'—0"	6'—6"	0'—5"	3/8" @ 6" c.c.	3/8" @ 8" c.c.	6" c.c.
7.	5000	12'—0"	7'—6"	0'—6"	3/8" @ 5" c.c.	3/8" @ 8" c.c.	6" c.c.
8.	7500	14'—0"	8'—6"	0'—6"	3/8" @ 4" c.c.	3/8" @ 7" c.c.	6" c.c.
9.	10,000	15'—0"	9'—6"	0'—6"	½" @ 6" c.c.	3/8" @ 6" c.c.	5" c.c.
10.	20,000	20'—0"	10'—3"	0'—7"	½" @ 5" c.c.	" @ 6" c.c.	5" c.c.

18. Square Tanks I : 2 : 4 Mixture.

No.	Capacity in Gallons	Size of Tank		Thickness of Concrete for walls and floor	Reinforcement		
					Walls		floor
		Length & Breadth	Depth		Spacing of horizontal bars	Spacing of vertical bars	3/8" bars
1.	500	5′×5′	3′–6″	4″	¼″ @ 6″ c.c.	¼″ @ 6″ c.c.	9″ c.c.
2.	750	6′×6′	3′—6″	4″	¼″ @ 6″ c.c.	¼″ @ 6″ c.c.	9″ c.c.
3.	1000	6½′×6½′	4′—0″	4″	¼″ @ 6″ c.c.	¼″ @ 6″ c.c.	8″ c.c.
4.	1500	7½′×7½′	4′—6″	4½″	3/8″ @ 9″ c.c.	3/8″ @ 9″ c.c.	7″ c.c.
5.	2000	8′×8′	5′—6″	4½″	3/8″ @ 9″ c.c.	3/8″ @ 6″ c.c.	6″ c.c.
6.	3000	9′×9′	6′—6″	5″	3/8″ @ 7″ c.c.	½″ @ 7″ c.c.	7″ c.c.
7.	5000	11′×11′	7′—6″	5½″	3/8″ @ 6½″ c.c.	5/8″ @ 6″ c.c.	6½″ c.c.
8.	7500	13′×13′	7′—6″	6″	3/8″ @ 6″ c.c.	5/8″ @ 7″ c.c.	6″ c.c.
9.	10,000	14′×14′	8′—6″	7″	½″ @ 9″ c.c.	5/8″ @ 6″ c.c.	3″ c.c.

19. Pressed Steel Tanks, 4 ft. deep.

Length & breath	Gallons	No. of plates	Weight in Cwt.
4×4	400	5	6
8×4	800	8	13
12×4	1200	11	17
16×4	1600	14	22
8×8	1600	12	19
12×8	2400	16	25
16×8	3200	20	31
20×8	4000	24	37
12×12	3600	21	33
16×12	4800	26	40
20×12	6000	31	48
24×12	7200	36	56
12×12	3600	21	33
16×12	4800	26	40
20×12	6000	31	48
24×12	7200	36	56
28×12	8400	41	64
16×16	6400	32	50
20×16	8000	38	59
24×16	8600	44	68
28×16	11200	50	77
32×16	12800	56	87
20×20	10000	45	70
24×20	12000	52	85
28×20	14000	59	96
32×20	16000	66	108
36×20	18000	73	144
40×20	20000	80	132
24×24	14400	60	97
28×24	16800	68	112
32×24	19200	76	125
36×24	21600	84	140

L×B in ft.	Gallons	No. of Plates	Weight in Cwts.
40×24	24000	92	152
28×28	19600	77	128
32×28	22400	86	140
36×28	25200	95	156
40×28	28000	104	173
32×32	25600	96	158
36×32	28800	106	174
40×32	32000	116	194
36×36	32400	117	195
40×36	36000	128	216
40×40	40000	140	236

20. Pressed Steel Tanks, 8 ft. Deep.

4×4	800	9	16
8×4	1600	14	26
12×4	2400	19	36
16×4	3200	24	45
8×8	3200	20	38
12×8	4800	26	49
16×8	6400	32	61
20×8	8000	38	72
12×12	7200	33	67
16×12	8600	40	76
20×12	12000	47	90
24×12	14400	54	103
28×12	16800	61	116
16×16	12800	48	92
20×16	16000	56	107
24×12	19200	64	123
28×16	22400	72	136
32×16	25600	80	153
20×20	24000	64	125
24×20	24000	74	143

L×B in ft.	Gallons	No. of Plates	Wt. in Cwt.
28×20	28000	83	165
32×20	32000	92	182
36×20	36000	101	198
40×20	40000	110	220
24×24	28800	84	109
28×24	33600	94	186
32×24	38400	104	212
36×24	43200	114	228
40×24	48000	124	247
28×28	39200	105	210
32×28	44800	116	178
36×28	50400	127	254
40×28	56000	133	280
32×32	51200	128	258
36×32	57600	140	284
40×32	64000	152	308
36×36	64800	163	310
40×36	72000	166	338
40×40	80000	180	369

21. Pressed Steel Tanks, 12 ft. deep.

4×4	1200	13	26
8×4	2400	20	41
12×4	3600	27	56
16×4	4800	34	70
8×8	4800	28	58
10×8	7200	36	74
12×8	9600	44	90
20×12	12000	52	107
12×12	10800	45	91
16×12	14400	54	110
20×12	18000	63	130
24×12	21000	72	148

L × B in ft.	Gallons	No. of Plates	Weight in Cwt.
28 × 12	25200	81	167
16 × 16	19200	64	130
20 × 16	24000	74	151
24 × 16	28800	84	175
28 × 16	33600	107	221
32 × 16	38400	118	243
20 × 20	30000	129	264
24 × 20	36000	140	287
24 × 24	43200	108	221
28 × 24	50400	120	346
32 × 24	57600	132	271
36 × 24	64800	144	296
40 × 28	84000	172	352
32 × 32	76800	160	329
36 × 32	86400	174	358
40 × 32	96000	188	386
36 × 36	97200	189	389
40 × 36	108000	204	420
40 × 40	129000	220	454

22. Staircases (R.C.C.).

Live load should be as follows :

(*i*) For residential buildings ... 80 lbs./sq. ft.

(*ii*) For offices and hotels ... 100 lbs/sq. ft.

(*iii*) Public buildings ... 120 lbs/sq. ft.

Note. Balustrades of stairs may be designed as cantilever with horizontal load of about 25 lbs per linear foot for residential buildings and 50 lbs for public buildings. These loads will be taken as acting at tip of the balustrades.

23. Fence posts.

Fence posts should be 9 ft. apart unless steel droppers are fixed to fencing wires, usually at 6 ft. intervals, to keep the wires the correct distance apart. If the fencing wires are pulled sufficiently tight the use of droppers enables the line posts

(*i*) Stays are of the same size as straining posts with same reinforcement.

(*ii*) For a post that tapers to a smaller section at the top the correct reinforcement for the whole post is that suitable for the sectional dimensions of the bottom.

27. Cantilever and Balconies.

Thickness of cantilever slab at the support is span 17·5. Tensile reinforcement is provided at the top. End of the cantilever slab in the wall can be anchored down by means of iron rods embedded in the supporting walls or pillars. Where there is no sufficient weight of wall over the end sufficient on-charge to counterbalance the weight of the projection is essential. In cantilever bars should not be used less than $\frac{1}{2}$″ dia.

28. R.C.C. Sunshade.

About No. 10 wire is provided at 12″ c.c. at right angles to bars of $\frac{1}{4}$″ dia at 6″ c.c. for 2′—6″ sunshade. End corner of concrete $1\frac{1}{2}$″ 8″ embedded in wall. 3″ thick at the start near wall and $1\frac{1}{2}$″ at the end. Slope as desired.

29. Water-Cement Ratio.

Gallons per cwt. ...	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8
By weight ...	·36	·40	·45	·49	·54	·58	·63	·67	·72

30. Grades of Aggregate.

3/16″—3/4″ is suitable for reinforced works.

(1 : 2 : 4). Not less than 5 p.c. and not more than 30 p.c. should pass through no. 52 B.S. sieve.

(*i*)	Passing 3/4″ mesh ...	100 p. c.	Coarse
	Passing 3/8″ mesh ...	55—65 p. c.	,,
(*ii*)	Passing 3/16″ mesh ...	35—42 p. c.	Fine
	Passing No. 100 B.S. sieve ...	3 p. c.	,,

(*a*) *B.S.S. No. 63*

Coarse aggregate—		For small quantities.
6 parts	$2\frac{1}{2}''$	
4 parts	$1\frac{1}{2}''$	3 parts of $2\frac{1}{2}''$
2 parts	$\frac{3}{4}''$	$1\frac{1}{2}''$ parts of 3/8″
1 part	$\frac{1}{4}''$	

(*b*) *Medium aggregate*—

5 parts	$1\frac{1}{2}''$	3 parts $1\frac{1}{2}''$
2 parts	$\frac{1}{2}''$	$1\frac{1}{2}''$ parts 3/8″

(*c*) *Fine aggregate*—

5 parts	3/4″
1 part	3/8″
1 part	1/8″

(*d*) *Very fine aggregate*—

3 parts	3/8″
1 part	1/8″

(*e*) Sand : While passing 1/8″ screen not more than 30% passing a 1/30″ screen, not more than 60% passing a 1/16″ screen. A well graded sand and stones should have voids between 20 and 30% and if more it needs regarding. Percentage of voids can be tested by a simple method : by filling a measured

tin with water and aggregate. The proportions specified are dry materials.

(f) Grading limits for coarse aggregates. B.S.S. No. 882 1944

B.S.S.	1½″	¾″	½″	3/8″	3/16″
1½″ to 3/16″	95—100	30—70		10—35	0—5
¾″ to 3/16″	100	95—100		25—55	0—16
½″ to 3/16″	—	100	90—100	40—85	0—10

(g) Mixtures for one bag of cement.

Mixture	Sand cft.	Coarse aggregate cft.	Water in in gallons
1 : 1¼ : 2	1¼	2½	4½
1 : 2 : 3	2½	3¾	5
1 : 1½ : 3	2¼	3¾	5
1 : 2 : 4	3¼	5	5½
1 : 2½ : 5	4	6¼	6
1 : 3 : 6	5	7½	6½

Sand is assumed to be 30% damp and contains a gallon of water in each cft.

(*h*) *Grading of sand.*

B.S. Sieve	Percentage passing grades A and B	
	A	B
3/16″	—	95—100
No. 7	95—100	70—95
,, 14	60—80	45—85
,, 25	—	25—60
,, 52	10—20	5—30
,, 100	0—3	0—10

Notes. (*i*) Fine sand need more cement and should not be used in excess.

(*ii*) For foundations mixture line 1 : 4 : 8, 1 : 5 : 10 and 1 : 6 : 12 can also be used.

31. (*a*) **Classification of works.**

	Mixture	Work
(*i*)	1 : 1½ : 2	Work of this section *viz.* fence posts and small precast work.
(*ii*)	1 : 2 : 3 or 1 : 2½ : 3	Water tight works, floors, pavements, walls, tanks, pits, steps, paths, surface of 2nd coarse rods R.C.C. work of extra strength, piles etc.

	Mixture	Work
(*iii*)	1 : 2 : 4	Ordinary used for concrete works *viz.* mass walls above ground, road slabs and general R.C.C. Works.
(*iv*)	1 : 2½ : 5	Mass concrete work of ordinary class, such as basis of machinery, walls below ground.
(*v*)	1 : 3 : 6	Rough type works as foundation of large structures etc.

(*b*) **Sizes of Aggregate for sections.**

Min. size of Section	R.C.C. works *viz.* Walls, Beams Columns	Concrete Works	Heavy R.C.C. viz. Slabs	Light R.C.C. or Concrete Slabs
2½″ to 5″	½″—¾″	¾″	¾″—1″	¾″—1½″
6″ to 11″	¾″—1″	¾″—1½″	¾″	¾″—1½″
12″ to 29″	¾″—1″	1½″	¾″—1″	¾″—1½″
30″ and over	¾″—½″	1½″	¾″—1″	¾″—1½″

30. Cinder Concrete.

1 : 10 (1 Cement—10 Cinders). This is light and porous. Has good heat insulating properties, can be laid on top of roof about 2″ thick and slope of not less than 1 in 48 with top layer of $1\frac{1}{2}$″ of water-proof cement concrete, with layer of water-proof sheets or paper in between cinder and concrete layers, as cinder concrete is not water-proof.

31. Steel.

(*i*) A thin rust on the steel is not considered harmful, but any loose or scaly rust must be completely removed before use. Grease or paints to be cleaned properly. If steel rods are to be stored, these may be given a cement wash to guard against rusting.

(*ii*) As far as possible welding is to be avoided. But may be permitted at joints where steel is not subject to more than 75% of maximum permissible stresses and welds should be so staggered that at any one section not more than 5% of the rods are welded.

32. Cement.

(*a*) *Weight of Cement and its measurements.* Cement weighs 75—90 lbs/cft when loose packed, 110 lbs/cft when well packed and its weight varies per cft. according to degree of compaction. Cement should be measured by weight and not by volume, taking say 90 lbs/cft. A bag of cement weighs 1 cwt=1·2 cft.

(*b*) Cement exposed to atmosphere or in touch with moisture of any kind looses strength, but 1 to 2% of water has no effect on cement. If the absorption is more than 5% cement becomes lumpy.

Cement should be stored in a dry room on a raised wooden platform 6″ to 9″ above floor and 12″ away from walls. Bags not to be stored more than 10 in each layer. A bag of cement $1\frac{7}{8}$ cft. occupies $3\frac{1}{4}$ sq. ft. of floor space.

(*c*) *Test of Cement.* A little square of 2″ thick of cement paste should be dried in ordinary room and should commence to set in about 30 to 60 minutes. In 18 to 24 hours this

should harden to resist any impression as a thumb nail. In 48 hours it will be difficult to break with fingers and becomes very hard in 7 to 8 days if properly cured. Cement keeps up setting for one year and strength increases day by day.

Deteriorated cement if passes No. 200 sieve to the extent of 78% may be used in place of lime equal to 1 : 2.

Note. Rapid hardening cement sets in 2 or 3 days and ordinary in 28 days.

33. Test of proportion of clay in sand.

Take a glass tumbler. Put 2″ sand and fill with water, stir well and leave it to settle for about an hour. Sand will settle slowly if layer of clay is more than $\frac{1}{8}$″ over 2″ sand. Sand needs washing. More than 6% clay is harmful. Sand should be free from particles of shell. Organic materials in sand are harmful.

34. Important Points of Cement Concrete.

(*i*) Air voids to be avoided. Only 5% of air voids will reduce strength by 30%.

(*ii*) Badly compacted concrete will develop honeycombs or porous concrete will lead to the corrosion of any reinforcement.

(*iii*) Materials should be accurately measured.

(*iv*) Should be mixed properly to have uniform mix and colour, 15 to 18 revolutions of mechanical mixer can mix the materials properly.

(*v*) Hand mixing should be done on a water-tight platform of 12′ × 7′ or 10 sq. ft. (min), with arrangements to prevent the materials or water being spread on earth. 10% of cement to be added more if hand mixed.

(*vi*) To be laid and consolidated in layers not exceeding 6″ for R.C.C. and 12″ for plain concrete. Before laying another layer laitance film should be removed and surface roughed. Care should be taken not to disturb the 1st layer concrete.

(*vii*) In filling columns, the concrete be poured into moulds in 3″ layers and constantly tampered and puddled with rods to

expel air bubbles. Too much trowelliug the concrete when plastic should be avoided as cement will come up, with resulting of cracking.

(*viii*) Sprinkling dry cement on newly laid concrete to be avoided which will result in cracks.

(*ix*) 20 bags of cement will :—

Lay a flooring for 3-roomed house (650 sq. ft.)

Or

Plaster the walls of 3 rooms of house (1300 sq. ft)

Or

Suffice for a drive way 50 ft. long, 8 ft. wide and $3\frac{1}{2}''$ thick.

Or

Build a compound wall 45 ft. long 4'-8" high.

Or

Make a precast fence post 6 ft. high and 4" square.

Or

Modernise the kitchen by providing for cooking platform, wall shelves, a sink etc.

35. Finish.

(*i*) To obtain proper finish, after form work is removed a cement wash can be brushed into surface by two coats. (Mix with properly screened fine sand.)

(*ii*) This wash can be rubbed with wood float.

(*iii*) Finished surface to be splashed with water two or three times a day for at least three days, for if the wash dries before it has attained its set, this will dust off.

(*iv*) A good appearance is obtained if work is rubbed with carborundum stone.

(*v*) To ensure bond of wash add 1 lb of commercial calcium chloride in five glasses of water and make the wash with it. (Do not use plain water.)

(*vi*) After rubbing with No. 20 carborundun stone or soapstones, wash and clean the surface. Fill voids with 1:2 cement mortar. The first rub to be applied when concrete is given; the late rubbing is difficult and does not give good results. The second rub after one month with No. 24 carborundum stone.

36. Defects in concrete and remedies.

(*i*) To avoid cracks, when temperature is cold and below 35° to 40°F. concrete operations should be discouraged. In tropical areas hot water should be used for mixing and richer mixtures are advisable.

(*ii*) Calcium chloride is used generally to accelerate hardening of cement. Proportion is 2 lbs to Cwt of cement.

(*iii*) Sweating is exudation of mixture on a concrete surface. The defect is seen where concrete work is known as crazing, *i.e.* invisible hair cracks. They do not decrease the strength of the concrete. The crazing occurs due to

(*a*) chemical action ;

(*b*) expansion and contraction, due to temperature or moisture changes ;

(*c*) Hair cracks are partially due to unequal shrinkage of surface concrete and mass behind it and generally result from the use of a mortar surface dressing too rich in cement. Too much watering. Insufficient curing or over-trowelling. To avoid crazing and hair cracks is to remove surface skin by hard brushing. Moist curing for long periods decreases the possibility of cracking.

(*iv*) *Corrosion of Reinforcement.* Penetration of moisture through porous concrete causes rusting of reinforcement. Cause being segregation of corners, edges and faces or at construction joints, while excessive fine sand leads to general weakness in concrete on account of high water-cement ratio which their use entails. The absence of sufficient fine sand below No. 52 mesh tends to give harsh working mixes prone to segregation and local defects. For concrete placed by hand, the sand contains not less than 15% passing No. 52 mesh, and values up to 20 or 30% are to be preferred. Lower values are suitable for concrete placed by vibration.

(*v*) Frost also has a destructive effect on weak and porous concrete The severest condition of frost action arise when concrete has more than one face exposed to the weather and is in such a position that it remains wet for long periods.

(*vi*) When reinforcing rods corrode, they in turn swell up in volume and throw off the covering concrete and become absolutely bare. The rusting goes on slowly through the porous concrete. A covering of cement plaster $\frac{1}{2}''$ to $\frac{3}{4}''$ thick not weaker than 1 : $2\frac{1}{2}$ applied on all doubtful faces will afford better protection. Rods may also be protected with cement Bitumastic paints and dusting with neat cement. This improves good adhesion.

37. Repairs to Concrete.

(*i*) Oil paints, cement paints, water paints, Distemper and also leeping of cowdung should be applied to fair cracks. Wide cracks should be grouted consisting of 1 cement 1 fine class washed sand The crack is sealed at the surface with cement paint or grout of stiff consistency applied with a brush, leaving openings at selected points for the liquid grout to be injected into crack. If the crack has penetrated throughout, it needs sealing on both sides.

(*ii*) Bulges may be carefully removed and rubbed with a grinding stone.

(*iii*) Patches may be filled with mortar of the mixture equal to conerete mix.

(*iv*) Application of silicate of soda. Cement when hardened contains a little amount of lime. The silicate of soda combines with this and with other calcium salts in the cement to form a glassy film. A soda of p. 84 grade of I. C. I. make is colourless liquid. One gal in 4 gals of water, should be sprayed with water core and rubbed with soft broom early and allowed to dry for 24 hours. and then next coat applied scrubbing each coat with water. In case of water tanks 2 parts of water and 1 part of soda is sufficient for both the coats.

38. Guniting of shot concrete.

A mixture of concrete is shot at pressure of 30/40 lbs per sq. in. from a cement gun.

Cement grit type	N—2	3/8″ dia.
,, ,, ,,	N—1	¼″ ,,
,, ,, ,,	N—0	1/8″ to ¼″ dia.

39. Old and New concrete.

All construction joints to be thoroughly racked, brushed and watered before new concrete is laid.

Concrete on both sides of old and new concrete junction should be quite dense. If the stoppage is of few hours then mortar grout of some proportion of actual mixture should be applied to old surface. When concrete is old, surface should be clipped away, wire brushed, moistened and neat, cement slurry applied, followed by application of a rich mortar 2 cement and 1 sand.

40. Removal of centering.

(*i*) For structures not carrying loads :—

Wall in mass work	... 3 days
Thin walls	... 2 days
Columns	... 2 days
Slabs, beams of small spans	... 7 days
Slabs, beams of large spans	... 18 days

(*ii*) Structure carrying loads (Heavy) :—

Sides not to be removed before 7 days below supports fo. 28 days. No loads should be allowed within 28 days.

Construction loads on centering should be taken as 50 lbs. to 75 lbs. per sq. ft. (load for wet concrete).

41. Spacing of M. S. Bars in-slabs

Diameters in Inches	Sectional Area of Steel per foot width of Slab when spaced as below.												
	2″	2½″	3″	3½″	4″	4½″	5″	5½″	6″	7″	8″	9″	10″	12″
¼	·29	·23	·20	·17	·15	·13	·12	·11	·10	·09	·08	·07	·06	·05
5/16	·46	·36	·31	·26	·23	·20	·18	·17	·15	·13	·11	·10	·09	·08
⅜	·66	·53	·44	·38	·33	·29	·26	·24	·22	·19	·17	·15	·13	·11
7/16	·90	·72	·60	·51	·45	·40	·36	·33	·30	· 6	·23	·20	·18	·15
½	1·18	·94	·78	·67	·59	·52	·47	·43	·39	·34	·29	·26	·24	·20
⅝	1·84	1·47	1·23	1·05	·92	·82	·74	·67	·61	·53	·46	·41	·37	·31
¾	2·65	2·12	1·77	1·51	1·39	1·18	1·06	·96	·88	·76	·66	·59	·53	·44
⅞	3·61	2·88	2·40	2·06	1·80	1·60	1·44	1·31	1·20	1·03	·90	·80	·72	·60
1	4·71	3·77	3·14	2·69	2·36	2·09	1·88	1·71	1·57	1·35	1·18	1·05	·94	·78
1⅛	5·96	4·77	3·98	3·41	2·98	2·65	2·39	2·17	1·99	1·70	1·49	1·33	1·19	·99
1¼	7·36	5·89	4·91	4·21	3·68	3·27	2·95	2 68	2·45	2·10	1·84	1·64	1·47	1·23
1⅜	8·91	7·12	5·94	5·09	4·45	3·96	3·56	3·24	2·97	2·55	2·23	1·98	1·78	1·48
1½	10·91	8·48	7·07	6·06	5·30	4·71	4·24	3·86	3·53	3·03	2·65	2·36	2·12	1·77

42. Area, Perimeters and Weights of M. S. Round Bars.

(1) AREAS

Diameter in Inches of Bars		3/16″	¼″	5/16″	3/8″	7/16″	½″	5/8″	¾″	7/8″	1″	1⅛″	1¼″	1 ″	1½″
Areas for Number of Bars Given in Column	No. of Bars														
	1	·03	·05	·08	·11	·15	·20	·31	·44	·60	·79	·99	1·23	1·48	1·77
	2	·06	·10	·15	·22	·30	·39	·61	·88	1·20	1·57	1·99	2·44	2·97	3·43
	3	·08	·15	·23	·33	·45	·59	·92	1·33	1·80	2·36	2·98	3·68	4·45	5·30
	4	·11	·20	·31	·44	·60	·79	1·23	1·77	2·41	3·14	3·98	4·91	5·94	7·07
	5	·14	·25	·38	·55	·75	·98	1·53	2·21	3·01	3·93	4·97	6·14	7·42	8·84
	6	·17	·30	·46	·66	·90	1·18	1·84	2·65	3·61	4·71	5·96	7·36	8·91	10·60
	7	·19	·34	·54	·77	1·05	1·37	2·15	3·09	4·21	5·50	6·96	8·59	10·39	12·37
	8	·22	·39	·61	·88	1·20	1·57	2·45	3·53	4·81	6·28	7·95	9·82	11·88	14·14
	9	·25	·44	·59	·99	1·35	1·77	2·76	3·98	5·41	7·07	8·95	11·04	13·36	15·90
	10	·28	·49	·77	1·10	1·50	1·96	3·07	4·42	6·01	7·85	9·94	12·27	14·85	17·67
2. Perimeter		·589	·785	·982	1·178	1·374	1·571	1·964	2·356	2·749	3·142	3·534	3·927	4·320	4·712
3. Wt./Ft. lb.		·096	·168	·361	·376	·511	·668	1·043	1·502	2·044	2·670	3·380	4·172	5·049	6·008

CHAPTER ONE

1. British Standard Sieves (B.S.)

Sieve size or No.	Nominal size of aperture, inches.		Sieve size or No.	Nominal size of aperture, inches	
1½"	1½		No. 25	0·0236	¼"
¾"	¾		No. 30	0·0232	
3/8"	3/8		No. 36	0·0166	1/60"
3/16"	3/16		No. 44	0·0139	1/72"
No. 4	0·187		No. 50	0·0117	
No. 5	0·1320	1/8"	No. 52	0·0116	1/82"
No. 7	0·0949	1/10"	No. 72	0·0083	1/120"
No. 8	0·09		No. 100	0·0060	1/165"
No. 10	0·0660	1/15"	No. 120	0·0049	
No. 12	0·0553		No. 150	0·0041	
No. 14	0·0474	1/21"	No. 170	0·0035	
No. 16	0·0469		No. 200	0·0030	
No. 18	0·0336	1/41"			

2. American Standard Sieve.

U. S. sieve No.	Size of aperture, inches.	Approx. B. S. Sieve No.	Tyler's Sieve No.
4	0·187	3/16'' or 4	4
8	0·0937	7	8
10	—	8	—
16	0·0469	14	14
30	0·0232	25	28
40	—	36	—
50	0·0117	52	48
100	0·0059	100	100
200	—	200	—

3. Wire Mesh.

Mesh size, inches.	Thickness of wire for sieve	
	S. W. G,	Inch
1×1	9	0·144
½×½	9	0·144
⅓×⅓	11	0·116
3/8×3/8	12	0·104
¼×¼	13	0·092
1/8×1/8	15	0·072
1/16×1/16	17	0·056

4. British and Metric Equivalent

To convert	Into	Multiplier	Reciprocal
Inches	Millimetres	25·40	1·0394
Feet	Metres	0·3048	3·2809
Yards	Metres	0·9144	1·0936
Miles	Kilometres	1·6093	0·6214
Sq. inches	Sq. Centimetres	6·4514	0·155
Sq. feet	Sq. Metres	0·0929	10·7643
Cub. inches	Cu. Centimetres	0·0283	35·3166
Pints	Litres	0·5679	1·7608
Lbs. (pounds)	Kilogrammes	0·4536	2·2046
Tons	Tonnes	0·9842	1·0161
Ft. pounds	Kilog Metres	0·1382	7·2331
Lbs./sq. inch	Kilos/sq. cm.	0·0703	14·223
Lbs./ft.	Kilos/sq. metre	4·8826	0·2048
Lbs./yard	Kilos/metre	0·4961	2·0159
Tons/sq. inch	Kilos/sq. mm.	1·5749	0·6350

5. Materials required for 100 sq. ft. of mortar.

(No allowance of wastage is given below in Table)

	1 : 1	1 : 1½	1 : 2	1 : 2½	1 : 3	1 : 4	1 : 6	1 : 8
	Mixtures							
Thickness	c—s	c—s	c—s	c—s	c—	c—s	c—s	c—s
3/8″	1·8—2·2	1·5—2·6	1·2—2·9	1·0—3·1	0·9—3·3	0·7—3 4	0·5—3·7	0·4—5·1
½″	2·4—2·9	1·9—3·5	1 7—3·9	1·4—4·2	1·2—4·4	1·0—4·6	0·7—4·9	0·5—5·1
¾″	3·6—3·3	2·9—5·3	2·5—5·9	2·1—6·3	1·8—6·6	1·4—6·9	1·0—7·4	0·8—7·7
1″	4·8—3·8	3·9—7 0	3·3—7·8	2·8—8·4	2·4—8·8	1·9—9·2	1·4—9·8	1·1—10·2
1¼″	6·0—7·2	4·8—8·8	4·1—8·8	3·5—10·4	3·0—11·0	2·4—11·5	1·7—12·3	1·3—12·7
1½″	7·2—8·7	5·8—10·5	4·9—11·8	4·2—12·5	3·6—13·1	2·9—13·8	2·0—14·8	1·6—15·3
2″	9·6—11·5	7·8—14·0	6·6—15·7	5·6—16·7	4·8—17·5	3·8—18 3	2·7—19·7	2 1—20·4

C=Cement. S=Sand

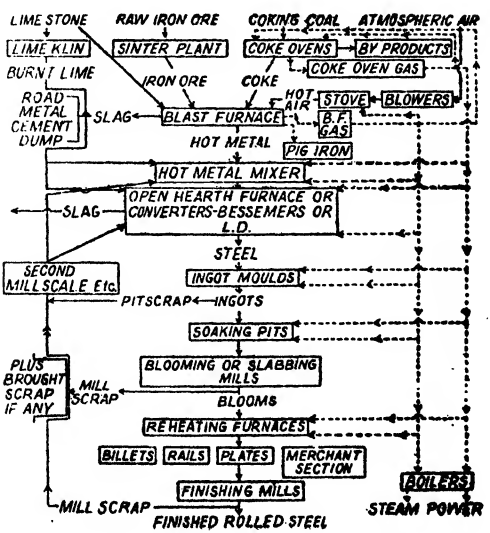
6. Rails and Channels.

90 lbs. Rail	8″×4″	90 lbs.	Channel	9″×3″
75 ,, ,,	7″×4″	75 ,,	,,	8″×3″
60 ,, ,,	6″×3″	60 ,,	,,	6″×3″
50 ,, ,,	5″×3″	25 ,,	,,	4″×2″

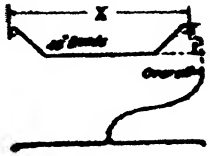
7. Spring Steel Flats. *Lbs./Foot*

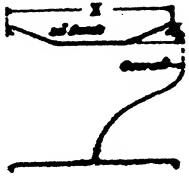
Size Thickness.	¾″	1″	1¼″	1½″	1¾″	2″	2¼″	2½″	3″
3/16″	·478	·638	·797	9·57	—	—	—	—	—
¼″	·636	·850	1·06	1·28	1·49	1·70	—	—	—
5/16	—	—	—	1·59	1·86	2·12	2·39	2·65	—
3/8″	—	1·28	1·59	1·92	2·23	2·55	2·87	3·19	3·83
1/2″	—	1·70	—	2·25	2·98	3·40	3·83	4·25	5·10

Steel Manufacture

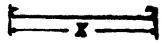


8. Bar Bending Schedule





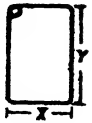
Size of Bars	X	½″ to 5/8″	¾ to 7/8′	1″	1⅛″ to 1¼″
		X+1′—0″	X+1′—2″	X+1′—4″	X+1′—6″
Over All	9¾″ to 13¾″	X+1′—5″	X+1′—7″	X+1′—9″	X+1′—11″
	14¾″ to 18¾″	X+1′—7½″	X+1′—9½″	X+1′—11½″	X+2′—1½″
	24¾″ to 28¾″	X+2′— ½″	X+2′—2½″	X+2′—4½″	X+2′—6½″
	29¾″ to 33¾″	X+2′—3″	X+2′—5″	X+2′—7″	X+2′—9″
	9¾″ to 13¾″	X+1′—10″	X+2′—0″	X+2′—2″	X+2′—4″
	14¾″ to 18¾″	X+2′—3″	X+2′—¾″	X+2′—7″	X+2′—9″
	19¾″ to 23¾″	X+2′—8″	X+2′—10″	X+3′—0″	X+3′—2″
	24¾″ to 28¾″	X+3′—1″	X+3′—3″	X+3′—5″	X+3′—7″
	29¾″ to 33¾″	X+3′—6″	X+3′—8′	X+3′—10″	X+4′—0″



1x+6″ for 3/16″ & ¼″——1x+8″ for 3/8″ 5/16″

2″ to 3″ add 1″

STIRRUPS



2x+2y+5½ for 3/4″ & ¼″

2x+2y+7½ for 5/16″, 3/8″, & ½″

Size of round bars...	¼″	5/16″	3/8″	½″	5/8″	¾″	7/8″	1″	1⅛″	1¼″
Area ...	·049	·077	·110	·307	·442	·601	·785	·994	1·227	
Weight/Foot ...	·167	·261	·375	1·043	1·502	2·044	2·670	3·379	4·173	

9. R. B. S. Beams.

R. S. Beams Lbs. per Lineal foot. Length up to 40 ft.

Dimension in Inches	Continental or Bazar Weight	Tata make	Dimension in Inches	Continental or Bazar Weight	Tata & British make
$3\times1\frac{1}{2}$	$4\frac{1}{4}$	4	$10\times4\frac{1}{2}$	—	25
$4\times1\frac{3}{4}$	$5\frac{1}{4}$	5	10×5	29	30
4×2	$5\frac{3}{4}$	—	10×6	38	—
4×3	$9\frac{1}{2}$	10	12×5	33	30
$4\frac{3}{4}\times1\frac{3}{4}$	$6\frac{1}{2}$	$6\frac{1}{2}$	12×5	—	32
5×3	10	11	12×6	42	44
$5\times4\frac{1}{2}$	—	18	12×6	—	54
6×3	12	12	13×5	—	35
6×5	25	25	14×6	48	—
6×6	25	—	15×5	—	35
$7\times3\frac{1}{2}$	15	15	15×5	—	42
7×4	17	16·01	15×6	—	45
7×7	35	—	15×6	—	58
8×4	19	18	16×6	—	50
8×5	$25\frac{1}{2}$	28	18×6	—	55
8×8	44	—	$20\times6\frac{1}{2}$	—	65
—	—	—	22×7	—	75
9×4	22	21	$24\times7\frac{1}{2}$	—	100

10. Materials required for 100 sq. ft. of concrete of various Depths. (90 lbs. of cement=one cft.)

Proportion	Materials	2″	2½″	3″	3½″	4″	4½″	5″	6″	8″	9″	10″	12″
1 : 1½ : 3	C	3.8	4.8	5.7	6.7	7.6	8.6	9.6	11.5	15.3	17.2	19.1	22.9
	S	6.9	8.6	10.3	12·0	13.7	15,5	17.2	20.6	27.5	30.9	34.3	41.2
	M	13.8	17.2	20.6	24.0	27.4	31.0	34.4	41.2	55.0	61.8	68.7	82.4
1 : 2 : 3	C	3·4	4.3	5.1	6.0	6.8	7.7	8.5	10.3	13.7	15.4	17.1	20.5
	S	8.2	10.3	12.3	14·3	16.4	18.6	20.5	24.6	32.8	36.9	41.0	41.2
	M	12.3	15.4	18.5	21·5	24.6	27.7	30.8	37.0	49.3	58.4	61.5	73.8
1 : 2 : 2 : 4	C	3.4	4·3	5.1	6.0	6.8	7.7	8.6	10.3	13.7	15.4	17.1	20.5
and	S	6.9	8·6	10.3	12.0	13.7	15.5	17.2	20.6	27.5	31.0	34.3	41.2
1 : 1⅓ : 3½	M	13.8	17.2	20.6	24.0	27.4	31.0	34.4	41.2	55.0	62.0	68.5	82.4
1 : 2 : 4	C	3.0	3.7	4.4	5.2	5.9	6.7	7.4	8.9	11.8	13.3	14 8	17.75
	S	7.1	8.9	10.7	12.5	14.2	16.0	17.8	21.4	28.5	32.0	35.6	42.7
	M	14.2	17.8	21.4	25.0	28.4	32.0	35.6	42.8	57.0	64.0	71.2	85.4
1 : 2½ : 5	C	2.5	3.1	3.7	4.3	4.9	5.5	6.1	7.4	9.8	11.0	12.2	14.7
	S	7.3	9.2	11.9	12.8	14.7	16.5	18.3	22.0	29.4	33.0	36.7	44.0
	M	14.6	18.4	22.0	25.6	29.4	33.0	36.6	44.0	58.8	66.0	73.4	88.0
1 : 3 : 5	C	2.2	2.8	3.3	3.9	4.5	5.0	5.6	6.7	8.0	10.0	11.2	12.5
	S	8.3	10.4	12·4	14.5	16.5	18.6	20.7	24.8	33.1	37.2	37.4	44.9
	M	13.8	17.2	20·6	24.1	27.5	31.0	34.4	41.3	55.0	62.0	74.8	89.8
1 : 3 : 6	C	2.1	2.6	3·1	3.6	4.2	4.7	5.2	6.3	8.3	9.4	11.4	12.5
	S	7.5	9.4	11·2	13.1	14.9	16.8	18.7	22.4	29.9	33.6	37.4	44.9
	M	15.0	18.8	22.4	26.2	29.8	33.6	37.4	44.8	59.8	67.2	74.8	89.8
1 4 : 8	C	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.8	6.4	7.2	8.0	9 6
	S	7.7	9.6	11.5	13.5	15.4	17.3	19.2	23.0	30.7	34.6	38.4	46.1
	M	15.4	19.2	23 0	27.0	30.8	34.6	38.4	46.0	61.4	69,2	76.8	92.2

C=Cement S=Sand M=Metal (Aggregate) in cubic feet.

(No allowance of wastage is in the table)

11. M.S. Angles.

Weight in lbs./Ft.

Sides in Inches Equal Angles	Thickness						
	1/8″	3/16″	¼″	5/16″	3/8″	½″	5/8″
¾×¾	0·58	0.48	1.12	—	—	—	—
1×1	0.80	1.16	1.49	—	—	—	—
1¼×1¼	1.01	1.47	1.91	—	—	—	—
1½×1½	1.23	1.79	2.34	2.86	3.33	—	—
1¾×1¾	—	2.11	2.76	3.39	3.98	—	—
2×2	1.65	2.43	3.19	3.92	4.92	—	—
2½×2½	—	—	4.04	4.98	5.90	7.65	—
3×3	—	—	4.89	6.04	7.17	9.35	—
3½×3½	—	—	—	7.11	8.45	11.05	13.55
4×4	—	—	—	8.17	9.72	12.75	15.67
5×5	—	—	—	—	12.28	16.16	19.93
6×6	—	—	—	—	14.82	19.55	24.17

12. Unequal M.S. Angles.

Sides in inches of unequal Angles	¼″	5/16″	3/8″	½″	5/8″	Sides in inches of unequal Angles	¼″	5/16″	3/8″	½″	5/8″
2×1¼	2.76	—	—	—	—	3½×2½	4.89	6.04	7.17	9.35	—
2½×1½	3.19	3 92	4.62	—	—	4×3	—	7.11	8.45	11.05	—
2½×2½	3.61	4.45	5.26	—	—	5×3	—	8.17	9.72	12.75	15.67
3×2	4 04	4.98	5.90	—	—	6×3	—	9.24	11.00	14.45	17.80
3×2½	4.89	5 51	6.54	8.504	—	6×4	—	—	12.28	16.16	19.93

13. M.S. Channels.

Weight in lbs. per foot.

Dimension in inches	Continental Weight	Tata & British weight	Dimensions in inches	Continental weight	Tata & British weight
$3\times1\frac{1}{2}$	5.5	5.27	9×3	19.4	17.46
$3\times1\frac{1}{2}$	...	5.09	$9\times3\frac{1}{2}$	22.3	22.27
4×2	8.0	7.91	10×3	20.7	19.28
4×2	...	7.092	$10\times3\frac{1}{2}$	24.5	24.46
$5\times2\frac{1}{2}$	11.0	10.22	$10\times3\frac{1}{2}$	—	23.55
6×3	14.5	12 41	10×4	30.2	30.16
7×3	17.6	14.22	$12\times3\frac{1}{2}$	26.1	26.37
$7\times3\frac{1}{2}$	20.2	18.28	$12\times3\frac{1}{2}$	—	25.25
8×3	19.3	15.96	12×4	36.5	31.33
$8\times3\frac{1}{2}$	22.7	20.21	15×4	42.0	36.37

Beams and channels are charged for at bazar weights as given, according to trade practice, irrespective of the actual weights and may vary considerably. Beams ordered in lengths of fraction of a foot, are charged as a whole foot *e.g.* 12′—6″ will be charged as 13 ft.

14. Galvanized Plain Sheets

Gauge B. G.	Size	Sheets per bundle	Standard weight per bundle in lbs.
16 G	6′×3′	5	237
	8′×3′	4	253
18 G	6′×3′	6	227
	8′×3′	5	252
20 G	6′×2′	12	242
	6′×3′	8	241
	8′×3′	6	241
22 G	6′×3′	10	243
	8′—3″	7	227
24 G	6′×3′	12	235
	8′×3′	9	235
	10′×3′	7	228
26 G	6′×3′	16	251
	8′×3′	12	251
	10′×3′	10	262
27 G	6′×3′	12	170
	6′×3′	16	226
	8′×3′	9	170

15. M.S. Hoops and Flats. (Weight in lbs. per lineal foot.)

Thickness, inches	1″	1¼″	1½″	1¾″	2″
1/16″	.213	.266	.319	.372	.425
1/8″	.425	.531	.638	.744	.85
3/16″	.038	.797	.956	1.116	1.275
1/4″	.85	1.06	1.28	1.49	1.70
5/16″	1.06	1.33	1.59	1.86	2.13
3/8″	1.28	1.59	1.91	2.23	2.55
7/16″	1.49	1.86	2.23	2.60	2.98
1/2″	1.70	2.13	2.55	2.98	3.40
5/8″	2.13	2.66	3.19	3.72	4.25
3/4″	2.55	3.19	3.83	4.46	5.10
7/8″	2.98	3.72	4.46	5.21	5.95
1″	3.40	4.25	5.10	5.95	6.80

Note.

(1) Calculate weight of other sizes as per e.g.— $2'' \times \frac{1}{2}'' =$ Twice $1'' \times \frac{1}{2}''$ or as same as $1'' \times 1''$, $4'' \times 1 =$ Twice $2'' \times 1/'$ and so on.

(2) Stock lengths 1/16″ thick 12 ft., 5/16″ and up 18 ft. Available in many sizes.

Hoop Iron Weight per 1000 ft		**Chequered Plates** 2″×1″ Chequar	
Size	lbs.	Size	lbs.
1″×18°	168·3	3/16″	8·75
1⅛″×18°	189·4	1/4″	11·50
1¼″×18°	210·4		
1″×19°	149·6	5/16″	13·50
1⅛″×19°	168·3	3/8″	16·25
1¼″×19°	187·0	1/2″	21·25
¾″×20°	99·9		

18. Wire and Sheet Metal Gauges.

Dia or Thickness in inches & mm.

Thickness Gauge	Standard Wire gauge		U. S. Standard	
	Inch	Millimetres	Inch	Millimetres
10	0·128	3·251	0·1406	3·572
11	0·116	2·946	0·1250	3·175
12	0·104	2·642	0·1094	2·778
13	0·092	2·337	0 0937	2·381
14	0·080	2·032	0·0781	1·984
15	0·072	1·829	0·0703	1·786
16	0·064	1·626	0·0625	1·588
17	0·056	1·422	0·0562	1·429
18	0·048	1·219	0·05	1·270
19	0·040	1·016	0·0437	1·111
20	0·036	0·914	0·0375	0·952
21	0·032	0·813	0·0344	0·873
22	0·028	0·711	0·03135	0·794
23	0·024	0·610	0·281	0·714
24	0·022	0·559	0·025	0·635
25	0·020	0·508	0·0219	0·556
26	0·018	0·457	0·0188	0·476
27	0·0164	0·4166	0·0172	0·437
28	0·0148	0·3759	0·0156	0·397
29	0·0136	0 3454	0·0141	0·357
30	0·0124	0·3150	0·0125	0·318
31	0·0116	0·2946	0·0109	0·278
32	0·0108	0·2743	0·0102	0·258
33	0·0100	0·2540	0·0094	0·258
34	0·0092	0·2337	0·0086	0·218

19. Tin Plates.

Theoretical weight of Tin plates is same as M. S. sheets plus allowance for Zinc Coating (10 oz per sq. ft.)

American Base Box			Gauge	British Base Box			
				14×20		20×28	
Gauge	Lbs.	Thickness		Sheets	Lbs.	Sheets	Lbs.
28	135	·0149	24	—	—	50	200
29	125	·0137	26	—	—	56	168
30	107	·0118	28	—	—	58	140
30·6	100	·0110	—	—	—	—	...
31·6	95	·0105	30	112	108	112	216
31·6	90	·0099	30·6	112	100	112	200
32	85	·0094	—	—	—	—	...
34	70	·0077	31·6	—	—	112	180
			—	—	—	—	...
			32·5	—	—	112	160
			34	—	—	112	140
			30 G×Size		10×20	225	156

20. M. S. Rounds 36 ft long Bars.

Dia-Inch	Wt. in lbs per bar	Dia-Inch	Wt. in lbs per bar.
½″	6·012	¾″	54·072
3/8″	14·00	7/8″	73·584
½″	21·048	1″	96·12
5/8″	37·548	1.1/8″	121·68
		1¼″	150.192.

21. M. S. Sheets. (Wt. in lbs./sq. ft.)

Thickness Gauge B. G.	Pounds	Thickness Gauge B.G.	Pounds	Thickness Gauge B.G.	Pounds
9	5·70	17	2·27	25	0·899
10	5·10	18	2·02	26	0·80
11	4·54	19	1·80	27	0·712
12	4·04	20	1 60	28	0·636
13	3·60	21	1·424	29	0·567
14	3·203	22	1·28	30	0·501
15	2·85	23	1·135	31	0 449
16	2·55	24	1·012	32	0·400

22. M. S. Plates (Wt. lbs./sq. ft.)

Thickness in Inches	Pounds	Thickness in Inches	Pounds
1/16″	2 55	¾″	30·60
1/8″	5·10	13/16″	33·15
3/16″	7·65	7/8″	35·70
¼″	10·20	15/16″	38·25
5/16″	12·75	1″	40·90
3/8″	15·30	1-1/8″	45·90
7/16″	17·85	1¼″	51·00
½″	20·40	1½″	61·20
9/16″	22·95	2″	81·60
5/8″	25·50	2½″	102·00
11/16″	28·05	3″	122·40

23. M. S. Tees (wt. in lbs. per foot)

(a) Sides in Inches Equal Sides	Thickness				
	1/8″	3/16″	1/4″	3/8″	1/2″
1×1″	0·82	1·17	1·51	...	...
1¼″×1¼″	1·03	1·50	1·93	...	...
1½″×1½″	1·25	1·81	2·36	...	...
2″×2″	...	...	3·21	4·64	...
2½″×2½″	...	...	4·07	5·9	...
3″×3″	...	...	...	7·20	9·38
3½″×3½″	...	..	...	8·49	11·08
4″×4″	...	...	...	9·77	12·79
(b) Unequal Sides.					
4″×3″	...	...	...	8·49	11·09
5″×3″	...	...	...	9·79	12·80
6″×4″	...	..	...	...	16·22

24. Principal Uses of B. R. C.

(Steel Fabric for R. C. C. works)

(*i*) Buildings :— (*a*) Floor and Roof slabs.

(*b*) Foundations.

(*c*) Shell type roof.

(*d*) Retaining walls with counterposts.

(*e*) Beams and column castings.

(*f*) Counters, shelves etc.

(*ii*) Concrete Road Runways.

(*iii*) Re-inforcement in gunniting works.

(*iv*) Swimming Pools, Tanks etc.

(*v*) Culverts, Bridges, Roadways, Pavements.

(*vi*) Hume pipes, Tunnels and Hangers.

Note :—(*i*) Finish should be plain.

(*ii*) Generally Galvanised for wires of 12″ gauge and lighter.

(*iii*) Width of Rolls 5 to 7 ft. Length of Rolls 150 —300 ft.

25. Welded Steel Wire Fabric For R. C. C. Works.

Conforming to either A. S. T. M., A/85-37 or B.S.S.—1221—Part—A—45

(Specifications OBLONGMESH.)

B S. S. Ref. No.	B. R. C. No.	Mesh Long Trans	Gauge Long Trans	Sectional Area/ft. Width sq. ft.	Weight of Fabric lbs. sq. yard.
101	1	3″×16″	4/o×4	0·503	16·35
102	2	3″×16″	3/o×4	0·435	14·
103	3	3″×16″	2/o×6	0·381	12·31
104	4	3″×16″	1/o×6	0·3351	10·93
105	5	3″×16″	1×6	0·2872	9·46
106	6	3″×16″	2×7	0·2430	8·00
107	7	3″×16″	3×8	0·2026	6·67
108	8	3″×12″	4×9	0·1716	5·75
109	9	3″×12″	5×10	0·1437	4·79
110	10	3″×12″	6×10	0·1178	4·00
111	11	3″×12″	7×10	0·0988	3·51
112	12	3″×12″	8×12	0·0816	2·77
113	13	3″×12″	10×12	0·0523	1·86

26. Welded Steel Fabric for R. C. C. Works.

Conforming to either A. S. T. M. A/185—37 or B. S.—1224—A—45

(Specifications SQUARE MESH)

B. S. S. Ref. No.	B. R. C. No.	Mesh Long Trans	Gauge Long Trans	Sectional Area/ft. Width sq. in.	Weight of Fabric lbs. sq yard
121	61	6″×6″	1×1	·1436	8·72
122	62	6″×6″	2×2	·1215	7·37
123	63	6″×6″	3×3	·1013	6·14
124	64	6″×6″	4×4	·0858	5·22
125	65	6″×6″	5×5	·0719	4·35
126	66	6″×6″	6×6	·0589	3·58
128	68	6″×6″	8×8	·0407	2·47
130	610	6″×6″	10×10	·0261	1·59

27. Commonly available Welded Fabric for R. C. C. Works.

Conforming to either A. S. T. M. A 185—37 or B. S. S.—1221—part A—45 (Specifications)

SMALL OBLONG MESH

Mesh Long Trans	Gauge Long Trans	Sectional Area per ft. width sq. inches.	Weight of Fabric lbs. per sq. yard.
3″×1″	10×10	·0524	6·40
3″×1″	5×10	·1431	9·16
3″×1″	8×8	·1389	10·03
3″×3″	10×10	·0524	3·17
2″×1″	12×12	0784	7·19
3″×2″	5×10	·1431	6·73
3″×2″	8×8	·1389	6·21
3″×2″	10×10	·0524	3·96
2″×2″	6×10	·1767	7·78
2″×3″	5×10	·2149	8·13
2″×2″	10×10		4·79

28. Galvanzed Sheets. (Bundle weighs 2 Cwt.)

Plain Sheets. Size 6′×3′ 8′×3

Thickness Gauge	Corrugated Sheets Length/Breadth	6′	7′	8′	9′	10′	11′	12′
18	10/3	6	5	5	4	4	—	—
20	,,	8	7	6	5	5	—	—
22	,,	10	8		6	6	—	—
24	,,	12	10	9	8	7	—	6
26	(180 lbs.)	12	10	9	8	7	—	6
24	8/3	16	14	12	11	10	—	8
26	1/3	14	12	10	9	8	7	7

CHAPTER I

1. Survey and Field Work.

(*i*) Examine the adjustment of the instruments and test length of the chain before commencing the survey or field work.

(*ii*) Choose the best line for Roads paying attention to Bridges over long rivers etc.

(*iii*) The line should cross the river or crossings at right angles and with easy curves.

(*iv*) In chaining make a fresh start at every mile and not at every station.

(*v*) Permanent Bench marks to be fixed in each mile and its position marked on the plan and level books.

(*vi*) Important marks such as towns, rivers, tanks, temples and isolated trees to be includsd in survey.

(*vii*) In cases of hills, peaks, spurs and termination of ranges should be fixed bearings and angles.

(*viii*) Position of buildings and metal stone quarries to be fixed, if within half a mile of the line, with materials obtained.

(*ix*) Description of soil surveyed.

(*x*) Pits or borings for trial to be sunk or dug up to 10 ft.

(*xi*) High Flood level (H.F.L.) of Bridges or Crossing points to be obtained and noted.

CHAPTER II

2. Three Screw Instruments.

(1) *Light, Dumpy level* (Builders level). These instruments are simple and strong construction. All sensitive points are closed in to protect from dust or rain. The instruments body and the spirit level receptacle cast in one piece. The

dumpy levels (Builders Levels) are applicable for all technical levelling work and are provided with measuring stadia lines 1,100. The level has a gradation to 360° or 400°, sub-graded to ½ degree around the ground plate. Reading is made on the front side.

This is for ordinary tacheometer work in slightly inclined areas.

Specifications. Analatic telescope for internal focusing.

Addition constant	Zero	Stadia lines	1 : 100
Length of telescope	$7\frac{7}{8}''$	Aperture of object glass	$1\frac{3}{16}''$
Magnification	25 dia.	Sensitiveness of spirit level	30″
Minimum Focus	5 ft.		
Weights Instrument	3·3 lbs	Horizontal circle diameter	4″
Container weight	5·5 lbs	Reading	1/10 degree
Tripod	9·9 lbs		

2. Light Engineer level with or without horizontal circle.

As per practice the probable error per mile both ways levelling is better than ± 2″. Consequently covering the whole range of levelling net-work for technical engineering purposes.

Specifications. Telescope, Analactic, astronomical, internal focusing coated optic.

Length of telescope	$7\frac{7}{8}''$	—Magnification	25 dia.
Aperture of object glass	$1\frac{3}{16}''$	Multiplication Factor	100
Minimum Focus	5 ft.	Horizontal circle Diameter	$2\frac{3}{4}''$
Addition constant	Nil	Gradation	1 degree resp. 1 grade

Direct reading	10 minutes
Estimation	1 minute

Sensitivity of spirit levels per 2 mm. arc of graduation.

Circular spirit level 8 minutes.

Tabular spirit level 30 seconds.

Weights instrument 4·4 lbs.

Metal container 5·3 lbs.

Sliding leg tripod 9·9 lbs.

3. **Light Engineers level.** (With tilting screw and coincidence spirit level), (with or without horizontal circle)

The level is fitted with a glass circle of hight standard direct to 10 minutes, estimation to 1 minute.

Specifications. Telescope.

Aralatic, internal focusing, coated optics.

Length of telescope	$7\frac{7}{8}''$	Horizontal circle	
Magnification	25X	Diameter	$2\frac{3}{4}''$
Aperture	$1\frac{3}{16}''$	Gradation	1″ resp. Ig
Minimum Focus	5 ft.	Direct reading	$\frac{1}{6}°$ resp. $\frac{1}{10}°$
Multiplication factor	100	Estimation	1′ resp. 1°.

Sensitivity of spirit level per 2 mm. arc of gradation.

Circular spirit level 8′.

Coinciding spirit level 30″.

Weights instruments 4·4 lbs. metal container 5·3 lbs.

Sliding leg tripod 9·9 lbs.

4. **Engineers Levels** (Precise levels).

Practice has demonstrated that mean error per 1000 yds. of double levelling amounts to ± 0·003 to ± 0·01 ft.

Specification. Analatic telescope with internal focusing.

Stadia lines 1 : 100 Addition constant zero

Length of telescope $9\frac{1}{4}''$

Aperture of object glass $1\frac{7}{16}''$

Magnification 32 dia.

Minimum Focus $6\frac{1}{2}$ ft.

Angle of field view 1 degree

Sensitiveness of circular spirit level 8 minutes.

Sensitiveness of tabular spirit level 20 seconds.

Diameter of glass circle $3\frac{1}{2}''$

Weight. Instrument 5·9 lbs. container 6·2 ibs. tripod 3·2 lbs.

Note. Measurements of angles can be taken with instruents without horizontal circle.

5. Fine Precision level (With optical micrometer).

The amount of the parallel displacement of the line of ght caused by the plane parallel disc is read in a separate icroscope adjacent the eye-piece. A scale permits direct read-g of 1/10th of the rod internal and estimation of 1/100.

Optical and mechanical data.

Analatic telescope with internal focusing coated optics.

Stadia lines 1 : 100 Addition constant zero

Length of telescope 15 in.

Aperture of object glass $2\frac{1}{4}''$.

Magnification power 50X.

Sensitiveness of circular spirit level 6′.

Sensitiveness of tabular spirit level 10″/2mm.

Tilting angle $\pm$ 1°.

Minimum focus $8\frac{1}{4}$ ft.

Weight of instrument 12·1 lbs.

Weight of container (16 in. × 10 in. × $8\frac{1}{2}$ in.) 8·8 lbs.

Weight of tripod with rigid legs 15 lbs.

6. Accessories.

(*i*) *Tripod.* Normally the precision level is supplied with a rigid tripod, but if desired can also be had a tripod with extension legs.

(*ii*) *Levelling rods* (Staff). Wooden precision rods as well as invar tape rods 3m. long with half centimeter graduation are available. If desired special boxes or canvas bags with leather corners for easy transportation are available.

(*iii*) Rod supporting base. Weight 15½ lbs.

(*iv*) *Field umbrella.* For protection against sunshine. It is generally in span of 6 ft and height of 7 ft. The ex-landable stick is provided with a steel point and can be taken in two parts for easy transportation.

The umbrella can be folded and carried with a leather strap.

(*v*) *Test meter.* The test meter for checking the rod graduation has either a rectangular or trapeze-shaped cross section. The exact length of the test meter is stated by the equatation, determined by Federal Department for Physics and Technics. The test meter is provided with magnifying glass on the 0 and 1 meter marks and an inlaid thermometer.

(*vi*) *Efficiency and accuracy of the Instrument.*

As practice has demonstrated a mean error of $\pm 0{\cdot}3$ to $\pm 0{\cdot}5$ mm. per kilometer of double levelling is well obtainable if all precautions for precise levelling work are complied with.

CHAPTER III

Four Screw Instruments

(1) *Light Dumpy level.* (Four Screw level)

Additional constant—Zero	Stadia lines 1 : 100
Length of telescope 7 7/8″	Aperture of object glass 1-3/16″
Magnifying power 25	Sensetiveness of spirit level 30″

Minimum focus 5 ft.

Weights. Instrument 5 lbs. Container 5·5 lbs. Tripod 13·2 lbs. Horizontal circle.

Diameter 4 in.

Reading 1/10 degree.

(2) *Engineers Level.*

The practice has demonstrated that the mean error per 1000 yds. of double levelling amounts to $\pm 0.003'$ to $\pm 0.01'$. Measurements of horizontal angles for terrain are possible.

Specifications. Analactic telescope with Internal focusing, erecting eye piece, coated optics.

Additional constant Zero. Stadia lines 1 : 100.
Length of telescope $9\frac{1}{4}''$.

Aperture of object glass $1 - 7/16''$. Magnification 32 dia.

Minimum focusing $6\frac{1}{2}'$. Angle of the field of view approx. 1 degree.

Sensitiveness of tabular spirit level 20″

Sensitiveness of circular spirit level 8′

Diameter of glass circle $3\frac{1}{2}''$

Weight. Instrument 8 lbs. Container 6·6 lbs. Tripod 13·21 lbs.

CHAPTER IV

Few More Four Screw Instruments

(*i*) *Dumpy Level* (Four Screws 18 in)

General Specifications. Telescope : Achromatic, erecting eye-piece. Internal focusing, coated optics. Length of telescope 18″.

Magnification. 32X. Aperture of object glass 1—3/16″.

Sensitivity of spirit level 20″.

Weight. Instrument 11·5 lbs. Case 9·7 lbs.

Tripod 13·2 lbs.

(*ii*) *18 in Wye Level* (Four Screw)

Specifications. Telescope : achromatic, erecting eye piec , internal focussing, coated optics.

Length of telescope 18 in.

Magnification 32 dia.

Aperture of object glass 1—3/16 in.

Sensitivity of spirit level 20 seconds.

Weight. Instrument 12·8 lbs.

Case 9·7 lbs.

Tripod 13·2 lbs.

(*iii*) *Convertible Level.*

Specification. Telescope, achromatic erecting eye piece. Internal focussing, coated optics. Length of teles ope 12 in.

Aperture of object glass $1\frac{1}{4}''$.

Magnification 25 dia.

Sensitiveness of spirit 60 seconds.

Diameter of horizontal circle 3—11/16 inch.

Diameter of vertical circle. 4—9/16 inch.

Weight : Instrument 9·5 lbs.

Case 6·4 lbs.

Tripod 11·5 lbs.

CHAPTER V

Theodolites

(*i*) *Builders Theodolite.*

Optic and mechanical specifications. Anlactic telescope with internal focusing lens, diaphragm with stadia hairs, relating telescope with eye piece. Addition constant Zero.

Stadia lines 1 : 100. Length of telescope 5—11/16 inch.

Aperture of object glass 1". Magnification 18 dia. Minimum Focus 40 in. Horizontal spirit levels parallel and at right

angles to horizontal axis each 60 seconds. Graduation on glass circle 360° or 400°. Dia. of horizontal circle $3\frac{1}{8}$ in

Direct reading by vernier microscope 30″ or 1°. Estimated reading 15″ or 50°. Dia. of vertical circle $2\frac{3}{8}$ in. Direct reading by main llne microscope 10′ or 10°. Estimated reading 1′ or 1°. Wt of Instrument 6·6 lbs. Tripod with extension legs 15·2 lbs. Metal container 6·6 lbs.

(*ii*) *Universal Theodolite.*

The great number of accessories make this modern instrument a suitable for almost all survey works above or below ground level.

Application. Traverse work, traingulation of lower order, contour work, layout surveys for construction, geodetic-astronomical orientations.

Telescope		Vertical circle.	
Analactic, astonomical, with internal focusing, coated optics, transitting at both ends.		Diameter	$2\frac{1}{4}$″
		Graduation	1 degree respec· 1 grade.
Length of telescope	$6\frac{3}{4}$″	Direct reading	1 minute.
Magnification	28 dia.	Estimation	0·1 minute.
Aperture of object glass	1—7/16″	Sensitivity of spirit level per 2 mm. arc of graduation.	
Minimum focus	4 ft.		
Additional constant	Nil	Circular spirit level	8 minutes.
Multiplication factor	100	Reversion spirit level	30 seconds.
Horizontal Circle		Plate spirit level	40 seconds.
Diameter	$3\frac{1}{2}$″	Vertical alli-dade spirit level	40 seconds.
Graduation	1 degree		

respectively 1 grade.

Direct reading	1 minute.	Weight :—	
Estimation	0·1 minute.	Instrument.	11 lbs.
		Metal container.	8·8 lbs.
		Sliding leg tripod	13·2 lbs.

Special features :— (*i*) Readings of both circles horizontal and vertical are taken with a scale microscope along side the telescope. Graduation 360 or 400 degrees.

(*ii*) Hand Lamp—For night observations and mining surveys the circle readings can be illuminated by detachable hand lamp.

(*iii*) Optical plummet—Precise centering is carried out with the aid of an optical plummet which is built into the revolving upper part of the instrument thus producing easy checking of lumbline adjustment.

(*iv*) Rigid plumb bob—A telescope plumbing staff which fits to the mounting screw of the tripod head can be used as rigid plumb bob in heavy wind or on trying terrain. A scale gives the height of instrument above the ground point being particularly convenient of tacheometric surveys.

(*v*) Compasses—For magnetic orientations a compass (Circular or tubular) can be attached to the theodolite.

(*vi*) *Eye piece prisms and diagonal eye piece* : For steep sights up to the zenith, eye piece prisms and long diagonal eye pieces are available. For sun observations the telescope prism is provided with a dark glass.

(*vii*) *Traverse equipment.* Additional traverse consisting of a switchable optical plummet for ground or roof marks and two targets for day or underground work can be delivered.

(*viii*) *Base subtense bar.* For optical distance measurements in the course of traverse work or for construction purposes a 2m. base substance bar with temperature compensation is fitted to the quick centering device of levelling head being interchangeable with the theodolite as well as with target and optical plummet. A small sighting mark in the centre of the

subtense bar can be used for taking bearings. An electrical illumination can be attached for night observation.

(*ix*) *Packing and transportation.* Normally the instrument is packed in a metal container. Minor accessories such as plump bob, sunshade etc. are kept in the container.

For railway transportation—upholstered box is necessary.

For field transportation—rucksack with belt.

(3) One Second Reading Theodolite "FT2".

New fennel one second theodolite is of latest development in design and construction is useful for high accuracy and is used for triangulation net-work.

Precise traversing geodetic and all sorts of engineering works. The reading of both circles are based on the principle of symmetrical light slits. The instrument is provided with an optical plummet and with self setting and centering device.

CHAPTER VI

Observation Instruments

(*i*) *Plane Table and Tripod* (*ALIDADE*).

Specifications :—

Length of telescope	8-7/8″
Aperture of object glass	1—7/16″
Magnification	20 dia.
Vertical circle	30″ or 1 degree.
Weight of alidade	7·9 lbs.
Weight of levelling head	6·2 lbs.
Weight of case	5·3 lbs.
Weight of plane table	7 lbs.
Weight of tripod	12 lbs.
Weight of canvas case	5·7 lbs.

Dimension of the case 1-21-7/8″ × H6¾″ width 8-7/8″.

(*ii*) *Clinometer.* This instrument is especially designed for finding the lines of ways with a determined percentual inclina-

tion and determination of per cent amount of declination for existing ways.

(*iii*) *Instrument for checking dams.* This instrument was originally designed for observation of changes on dams. However it is suitable for checking changes in the position of fixed points in districts affected by underground mining or in places subject to soil movements observations are made from fixed pillars which are covered with a cast iron or bronze plate with automatic centering device.

(*iv*) *Mountain Compass Transit.* This is used for determination of the station height as well as auxiliary levelling.

(*v*) *Universal Pocket Transit.* This pocket instrument is a very convenient and versatile for preliminary surveying on the surface or underground. It is suitable for forestry, geological and mining purposes. It is also good for simple contours and tracing works. By using camera tripod with ball joints the measurements of horizontal and vertical angles will be of greater convenience and precision. For maintenance the screw threads of compass and accessories ought to be brushed with gasoline and slightly greased.

(*vi*) *Cross Table* is heavy yet precise for construction. It is designed for adaption of observation instruments, *viz.*: Transit, theodolites, tacheometers, levels. If the heights of the instrument and target must be on the same level or if a fixed direction is given. Cross table is adjustable and changing of tripod heights. In conjunction with collimeter it is excellent device for adopting, instruments under adjustment. The perfect precision of the cross table guarantees reliable observations for all purposes.

Specifications:

Cross movement in 2 rectangular directions	5″
Height movement	12″
Weight	10 lbs.

CHAPTER VII

Observation Instruments for all Purposes

1. Builders level (3 and 4 Screws).
2. Light Engineers level (3 and 4 Screws).

3. Engineers Level (3 and 4 Screws),
4. Engineer's level with horizontal circle (3 and 4 Screws)
5. Fine precision level.
6. Abney level.
7. 18″ Dumpy level.
8. 18″ WYE Level.
9. Convertible level (Transit level).
10. $5\frac{1}{4}$″ Transit.
11. $6\frac{1}{4}$″ Transit.
12. 4″ Theodolite with vernier microscopes.
13. 5″ Precise Theodolite with microscopes (3 & 4 Screws).
14. 3″ Theodolite with optically reflected circle readings.
15. $3\frac{1}{2}$″ Theodolite with optically reflected circle readings.

CHAPTER VIII

Traverse Equipment

1. Over ground target.
2. Under ground target.
3. Optical plummet.
4. Auto-reduction tacheometer.
5. Suspension Mining Theodolite.
6. Instrument for checking movement of dams.
7. Fixed target.
8. Movable target.
9. Planetable outfit with auto reduction alidade.
10. Collimator.
11. Cross table.
12. Mountain compass.
13. Orientation Magnometer.
14. Clinometer with target.

Precision Observation Instruments.

1. Trough Compass.
2. Circular Compass.
3. Tabular Compass
4. Topographic protector.
5. Eye prism.
6. Clinometer.
7. Suspension Mining Compass with clinometer.
8. Topographic protector.
9. Geologists Compass.
10. Brunton Compass.
11. Mining Compass.

CHAPTER IX

Accessories

1. Levelling staff.
2. Suspension levelling staff.
3. Invar tape staff.
4. Special stadia staff.
5. Pocket staff.
6. Rigid plumb bob.
7. Staff level.
8. Plumb bob.
9. Base plate.
10. Test meter.
11. Measuring wedge.
12. Standard meter for testing staves and tape.
13. Survey or field umbrella.
14. Extension tripod.
15. Steel tape in leather case.
16. Metallic tape in leather case.

17. Steel tape on reels.
18. Survey chain.
19. Mining Engineer's Chain.
20. Mining Engineer's chain on reels.
21. Scale.
22. Tension bar.
23. Clamping handle.
24. Repair kit.
25. Tension handle.
26. Mine staff tape on reels.
27. Wire reel and plumb bob for shafts.

Following are some instructions for use of level

1. The leveller can take the staff reading distance and magnetic bearing simultaneously at his position at the eye piece of telescope without the trouble of moving it to the same.

2. The bubble of the spirit level is brought to the centre of its run by actuating the setting screw every time the reading is taken so that the necessity of bringing the bubble tube over two foot screws and centralizing the bubble and also repeating the same by turning the telescope through 90° is obviated.

3. The position of bubble whether in the centre or not is seen through the reflecting mirror or prism provided at the end of the bubble tube while the leveller is taking the staff reading.

4. Stadia wires are provided in the diaphragm so that distances can be computed without actual chaining.

5. For approximate setting up of the instrument a pill box level or circular level is provided which saves time.

6. A micrometer screw called the gradiometer screw which actuates the T-piece is graduated so that one turn gives a gradient 1/1000.

7. The instrument screws on to the stand and the focal length of the telescope vary in from 9·5″ to 11″.

How to set up the Level

Remove the level from the box, noting at the same time the position in which it is placed, so that it may be easily put back in the box in its proper position.

1. Screw the instrument on the stand and spread the legs of the stand so that the eye-piece of the telescope is just at the height of your eye.

2. Bring the bubble of the circular level to the central position approximately by means of the legs and accurately by means of the foot screws.

3. Bring the micrometer screw provided below the telescope to read zero when it will be seen that, if the instrument is in permanent adjustment the bubble of the large level will occupy the central position.

4. Turn the telescope to the staff, focus and bring the bubble of large level to the centre by means of micrometer screw by watching it from the eye-piece.

5. Now read the staff where the central wire of the diaphragm intersects it, say it is 6·82 ft. Book the reading. To read the distance depress the telescope by means of the micrometer screw so that one of the stadia wires reads a whole number, say 6·00 ; read the other stadia wire and say it reads 8 32 ft. ; the distance of the staff from level then equals 100 (8·32 — 6·00) = 232 ft.

6. To check and continue the work back the central wire to read 6·32 ft. on the staff when the bubble at the large level should be in the centre. The foot screws are not touched. Now take magnetic bearing if required.

PERMANENT ADJUSTMENT OF A LEVEL

There is only one permanent adjustment for level, namely the adjustment of the line of collimation. The object of this adjustment is to make the axis of the bubble tube parallel to the line of collimation.

Procedure.

1. Set up the level exactly midway between two pegs A and B fixed to the ground at a distance of not more than 300 ft. apart and level it as described before.

2. Take staff readings on pegs A and B. The bubble of the large level being brought to the central position by means of the gradienter screw or what is also called the micrometer screw while taking the staff readings.

3. The difference between the two staff readings gives the true difference in elevation between the two pegs A and B.

4. Shift the level to a position nearly one of the pegs A and B at a distance of about 1′ from the object and of the telescope and set it up as before and centralize the bubble of the large level by means of the micrometer screw.

5. Take again the readings on the staff kept over the pegs A and B. The reading of the staff kept over a peg which is very near the telescope may be conveniently taken by looking through object glass end of the telescope.

6. If the instrument is in adjustment, *i.e.* the line of collimation is parallel to the axis of the bubble tube, the difference in elevation between the two pegs A and B as obtained from the shifted po ition should be exactly the same as that obtained from the position.

7. If the instrument is not in adjustment, by means of the micrometer screw till the telescope so as to send the required calculated reading of the second peg.

8. It will be found that the bubble of the large level h as left its central position. Bring the bubble to the centre of its run by means of the capstan screws provided at the end of the bubble tube.

9. Now loosen the holding screw provided in the micrometer screw and revalue the engraved positition in its sleeve to read zero and tighten it in that position.

10. Finally complete the whole adjustment by bringing the bubble of the circular level (Pill box level) to the centre of its run by means of its own adjusting screw.

Therefore it follows that when the bubble of the pill box level is brought to the centre of its run by means of the legs of the stand and foot-screws, and setting the micrometer screw to read zero, the bubble of the large level will remain nearly in the centre of its run, indicating the horizontality of the axis of the bubble tube with the line of collimation parallel to it and therefore horizontal.

CHAPTER I

Roads and Earth Work

Construction of roads can be taken in 3 main parts :—

(1) Sub grade.

(2) Base.

(3) Surfacing.

Sub-Grade. The ground under the road, must be able to sustain satisfactorily the pressure of load on the road. The ground should be rolled properly before laying soling

Base. *The soling*—This is now generally specified for all important roads, except in areas where road is passing through rock or a very hard moorum.

The thickness is from 6″ to 9″ depending on soil width in 6″ border on either side of the metalling. Before metal is laid. The soling should be rolled with heavy steam road roller, in dry season, As far as possible rolling in rainy season should be avoided as the soling will settle unevenly. Before rolling the voids should be filled with hard moorum. The soling should be well hand-packed, with stones on their natural base. If round boulders are used, these should be broken before use. No stone to be less than 4″ or more than 9″.

Surfacing. Generally 6″ thick metalling is done, in layers of 3″. A 3″ layer should be spread and rolled, care being taken to get the edges rolled properly. To prevent the edges being spread, wet earth preferably with grass on it be dug and kept at edges as support. The edges should be quite straight. This may be done with a string of sufficient length.

Note. It is better to leave sub-grade for one season of rains before spreading soling or surfacing.

Curves. Curves on roads are necessary at a change of direction and at the road junctions.

(*i*) *Simple Curve* is a single circular arc connecting two

tangents, the point at which curve starts is point of curvature and ends in point of tangency.

(*ii*) *Compound Curve* is formed by two simple curves which have a common tangent and a common point of tengency, the curve lying on the same side of the common tangent.

(*iii*) *Reversed Curve* is formed by two simple curves which have a common tangent and a common point of tengency, the curve lying on opposite sides of common tangent. Reversed curves are ordinarily used to connect parallel lines.

Reversed curves if possible be separated by tangents of 200 ft. to provide proper transition of super-elevation.

(*iv*) *Compound Curve.* These are provided where there is sudden change of direction and are not generally provided since the abrupt change of curvature provides elements of danger, particularly at night.

More the fattened curve less the danger of accidents.

(*v*) *Vertical Curve.* This curve is provided at the intersection of two rising grades, *i.e.* at summit intersections, is a parabolic curve with offsets varying at the square of the distance from the crown at the curve. The shape of the curve is governed by the visibility required. For valley curves visibility is generally good. This curve is also laid at causeways. Minimum length of vision is 500 ft.

(*vi*) *Horizontal Curve.* In this case curves round a spur or obstructing vegetation, the same minimum length of vision of 500 ft. should generally apply.

The position of the vegetation above 3 ft. should be cut to give this visibility.

(*vii*) *Radii of Curves.* Minimum on plain roads 1000 ft.
Minimum on hilly roads 50 ft.

3. Ruling Gradients. (According to Road Congress)—

(*a*) For Plain Roads	1 in 30
For Hilly Roads	1 in 20
Maximum gradients	1 in 15 in stretches not exceeding 300 ft.

Gradient at curves not to exceed 1 in 30 and may be as flat as possible.

(*b*) **Road Gradients.**

Slope 1 inch	Rise per mile per ft.	Slope 1 in.	Rise per mile per ft.	Slope 1 in.	Rise per mile per ft.
15	352	20	264	28	189
16	330	22	240	30	176
17	311	24	220	33	160
18	293	25	211	35	151
19	278	27	196	37	143
40	132	70	76	120	44
43	123	80	66	125	42
45	117	91	59	150	40
50	106	100	53	200	27
55	96	110	48	300	20
60	88	115	46	400	13
				500	10

4. Camber.

Excessive Camber is uneconomical and is dangerous as it induces drivers to drive at crown, and should be avoided. Now-a-days comber is not given as far as possible except where there is much rain.

(*i*) Bituminous Roads in Towns	1 in 36 to 40
outside Towns.	1 in 48 to 60
(*ii*) Cement Concrete Roads	1 in 60 to 72
(*iii*) Moorum Roads	1 in 25 to 30
(*iv*) Foot paths	1 in 20 to 25

5. Cycle tracks.

6 ft. up to 2000 cycles per hour in multiples of 3 ft. per 1500 cycles more. Max. grade 1 in 20.

6. Foot paths.

It is taken 24" per 20 pedestrians per minute. Min. width 5 ft. Height should be 6 inches (min.) from Road edge level.

7. Dimensions of road-design vehicles.

(*Indian Road Congress*)

Maximum dimensions are as follows :

Width	96 inches or 8 ft.
Height—single decked	12 ft—6 inches
double decked	15 ft.—6 inches

Length :

(*a*) Single unit with two axles	35 ft.
(*b*) Single unit with more than two axles	40 ft.
(*c*) Semi-trailor-tractor combination	50 ft.
(*d*) Tractor and trailor combination	60 ft.

8. Super-elevation.

(*a*) All the curves with a radius of less than 1000 ft. should be super-elevated. Super-elevation being continued throughout the curve, the road surface being given a continuous cross fall from highest point to lowest point.

The transition from this cross fall to regular barrelling on straight reaches should be gradually worked off. The maximum super-elevation is limited to 1 in 10 or 1 in 12 to prevent transverse sliding of a vehicle at slow speed on a smooth road

(*b*) *Formulae for Super-elevation.*

C=Cross fall or super-elevation in ft/ft width of Road Surface.

S=Speed in m. p. h.

R=Radius of curve.

$$C = 0{\cdot}367 \frac{S^2}{R} = \frac{S^2}{15R}$$

(C) *Super-elevation.*

Roads subject to 30. m. p. h. Speed.	Roads not subject to limit
1 in 40 on curves of 800′ or over	1 in 15 on curves of less than 1200 ft.
1 in 30 on curves of 600′	1 in 17 on curves of less than 1400 ft.
1 in 25 on curves of 500′	1 in 19 on curves of less than 1600 ft.
1 in 16 on curves of 300′	1 in 22 on curves of less than 1800 ft.
	1 in 25 on curves of less than 2000 ft.
Super-elevation should not be less than camber of the road to Facilitate drainage.	1 in 30 on curves of less than 2500 ft.
	1 in 36 on curves of less than 3000 ft.
	1 in 38 on curves of less than 4000 ft.
	1 in 40 on curves of less than 5000 ft.

8. Horizontal Sight Distance (Indian Road Congress),—

Design Speed in m. p. h.	Safe stopping distance	Min. sight distance	Min. overtaking sight distance (Two lanes undivided)
	Absolute min. Sight distance (Two-lane undivided)	Overtaking distance on dual carriage ways. (Four lane width)	
	Ft.	Ft.	Ft.
15	90	—	—
20	120	200	300
25	160	250	450
35	250	450	800
40	300	550	1000
50	400	700	1450

Lane. Lane is assumed to be 4 ft. Minimum sight distance in which a driver, whose eye is assumed to be 4 ft. above the road surface can see object 4 in. high on the road. The

overtake distance is the distance along road in which a driver whose eye is assumed 4 ft. above can see object 4 ft. ahead above road surface (I. R. C.).

9. Curves (I.R.C.).

Flat Roads.			Hilly Roads.		
Speed m. p. h.	Min. radius in ft.		Speed m. p. h.	Min. Radius in ft.	
	Rule	Minimum		Rule	Minimum
50	1000	800	30	400	300
40	800	500	25	300	200
30	500	300	20	200	150
20	300	150	15	150	100

10. Extra width of Pavement for curves of all speeds (I. R. C.)

Radius of curve	Up to 200	201 to 500	501 to 1000	1001 to 1500
Extra width of pavement	4	3	2	1

Figures in the above (10) apply to pavements up to 22 ft. width only.

11. Minimum Transition length for various speeds and curve radii (I. R. C.).

Plain country					Hill tracts				
Radius in ft.	Min. transition length in ft. for speeds in m. p. h.				Radius in ft.	Min. transition length in ft. for speeds in m. p. h.			
Above	20	30	40	50	Above	15	20	25	30
3060	50	50	75	100	500	50	50	50	100
2000	50	50	75	150	450	50	50	50	100
1300	50	50	100	200					
1100	50	50	100	250					
1000	50	75	150	250	400	50	50	50	100
900	50	75	150	300	350	50	50	50	100
800	50	100	150	300	250	50	50	100	150
700	50	100	200	300					
600	50	150	200	300	200	50	50	100	—
500	75	150	250	—					
400	75	210	—						
300	100	250							
250	150	250							
200	200	—			150	100	100	—	—
150	250	—			100	100	—	—	—

12. Road Crossings. Best crossing is when the side roads join the major road, Railway line or the water ways at right angles.

13. Sizes of Motor vehicles.—(Cars)

Size	Max	Min	Ramps (for Repairs and Services)
Length	20	9′—10″	Max. rise 1 in 6
Width	6′—11″	4′—2″	Preferable 1 in 7
Height	7′—0″	5′—0″	

14. Minimum Turning Radii at Junctions.

(Turning speed less than 20 m.p.h.)

Angles of Junction	Radius of cars upto 20 ft. length	Radius of Bus or Trucks
90°	30 ft.	50 ft.
105°	35 ft.	60 ft.
120°	45 ft.	70 ft.
135°	60 ft.	90 ft.
150°	120 ft.	150 ft.

Generally roads are designed with 30 ft. or 35 ft. radius. In congested areas a kerb radius of 15 ft. be regarded as minimum.

15. Islands or Roundabouts.

Roundabouts are constructed where there is heavy traffic. Size of the central island should not be less than 100 ft. diameter.

The rule is that island should not be less than $\frac{1}{4}$th of the total of width of all radiating roads, subject to min. 25 to

35 ft., and max. 42 ft. A super-elevation of $\frac{3}{4}$" per ft. can be given. Weaving length should not be less than diameter of the island. Traffic rotaries should be on sloping ground with max. grade of not exceeding 1 in 30 for any road in the vicinity of rotary.

16. Table showing details of island.

Road Speed m.p.h.	Turning speed m.p.h	Min. radii of kerb of Cars in ft.	Min. radii of Trucks and Buses in ft.	Dia of island in ft. minimum	Width of carriage way round island in ft.	Super-elevation per ft. width	Min. weaving length
—	15	—	50	100	25 to 30	1	100
30	20	30	50	100	30	$\frac{3}{4}$"	110
35	25		100	150	30		150
40	30		130	250	50		180
50	35		150	380	—		210

17. Traffic Markings.

These are generally white lines 4" to 6" wide.

(*a*) On Highways 3 ft. lines with gap of 15 ft.

(*b*) In busy traffic road 3ft. lines with 3 ft. gap.

(*c*) At bends and near junctions. Central continuous line extending 100 ft in each direction beyond tangent points.

18. Car Parkings.

200 sq. ft. for each car. For parking parallel to the kerb, 8 ft. of additional pavement on each side should be provided for parking either diagonally or at right angles to the kerb, an extra width of min. 15 ft is required.

19. Steel lighting.

At road junction and islands it is important to see that

the lights are so placed that a driver can not only see from some distance away that he is approaching a junction but also see that route which he is to drive.

20. Road Rollers.

These vary in weight from 2 tons to 15 tons, hand, bullock, steam, petrol and diesel engine rollers.

Types of Road Rollers. (*i*) Cylindrical Roller. (*ii*) Sheeps Foot Roller. (*iii*) Pneumatic tyred or Wheeled Rubber tyred Roller. (*iv*) Tandem Rollers. (*v*) Three-wheeled Rollers.

Note. Max. grade a roller can climb is 1 in 5.

21. Materials required for one day's working.

(*i*) 8 to 10 tons roller for 8 hours' working.

1.	Steam coal or Fuel wood.	14 cft. or $8\frac{1}{2}$ maunds coal or 17 maunds fuel wood	A single cylinder roller will need 25% more fuel.
2.	Fire wood	8 seers	
3.	Kerosene oil	$\frac{1}{4}$ bottle	A Steam Road Roller can travel 8 miles with these materials per day.
4.	Cotton waste	$\frac{1}{2}$ lb.	
5.	Cylinder oil	$\frac{1}{4}$ gm.	
6.	Engine oil	$\frac{1}{3}$ gm.	
7.	Gear oil	$\frac{1}{8}$ gm.	
8.	Grease	$\frac{1}{4}$ lb.	
9.	Clean water	300 to 400 gallons	

(*ii*) *Washout materials needed every week.*

Kerosene	½ bottle	For cleaning brass mounts
Gear oil	¼ gallon	
Cotton waste	1 lb.	
Common oil	¼ bottle	Cleaning brass fittings
Boiled oil	½ bottle	For lead joints
Wool	1/32 lb.	For cill cup syphon
Copper wire	1/32 lb.	For joints trimmings
Red lead	½ lb.	For boiler joints
White lead	½ lb.	For boiler joints
Flax	½ lb.	For packing glands
Bar soap	2 cakes	For washing and cleaning
Special grease	¼ lb.	For stearing gear
Sticky grease	¼ lb.	For grease gear, for stearing and pump gear
Asbestos rope 1/16" thick	⅛ lb.	For packing glands

Asbestos mill board for mud holes 4 sq.ft. per year.

22. Standard Sizes of Broken Metal (I.R.C.).

Standard sizes	Passing sq mesh of size	Retained on sq. mesh of size
$2\frac{1}{2}''$	$3''$	$2''$
$2''$	$2\frac{1}{2}''$	$1\frac{1}{2}''$
$1\frac{1}{2}''$	$2''$	$1''$
$1''$	$1\frac{1}{2}''$	$\frac{3}{4}''$
$\frac{3}{4}''$	$1''$	$\frac{1}{2}''$
$\frac{1}{2}''$	$\frac{3}{4}''$	$\frac{3}{8}''$
$\frac{1}{4}''$	$\frac{3}{8}''$	1/10″
$\frac{3}{8}''$	$\frac{1}{2}''$	1/10″
Sand	1/10″	200 mesh to 1″

22A. Quantity of material required for premixed tar carpet for an area 2′ × 660′ × 18′.

1. *Base coat.*

About $1\frac{1}{2}''$ loose, layer of metal size $1\frac{1}{2}''$ to $\frac{1}{4}''$ — 2750 cft.
Of this 70% $1\frac{1}{2}''$ to $1''$ — 2050 ,,
And 30% is $\frac{3}{4}''$ to $\frac{1}{4}''$ — 700 ,,
High viscosity road tar 4 lbs/cft 11,000 lbs. 5 tons.

2. *Top coat.*

$\frac{1}{2}''$ to $\frac{1}{8}''$ chips at $4\frac{1}{2}$ cft/100 sft. — 1070 cft.
High viscosity road tar at 4 lbs/cft. — 1·90 ,,

3. *Seal coat.*

$\frac{1}{2}''$ to $\frac{1}{8}''$ chips at 4 cft./100 sft. — 951 ,,
High viscosity road tar at 33 per 100 sft. — 3·5 tons

Thicker asphaltic surfaces are necessary if the water bound macadam base is uneven or if the traffic is too heavy for $1''$—$1\frac{1}{2}''$

carpets. These may be either

(*i*) Premix asphalt macadam.

(*ii*) Semigrout asphalt macadam.

(*iii*) Asphaltic concrete.

(*iv*) Full grout asphalt macadam *or*

(*v*) Carpets $2\frac{1}{2}$"—3" thickness.

23. Black-Topping Materials.

Bitumen at 77°F penetrates as follows :

Cold climates 60 to 70.

Temperate climates 50 to 60.

Hot climates 40 to 50.

Penetration	*Work*
(1) 8/15—240°F melting point	Used in paint manufacturing.
(2) 20/30	Roofing, pipe jointing, coating of underground walls, electrical insulations, damp proof course, expansion joints in cement roads.
(3) 3/40	Grouting work, premixing and surface painting.
(4) 60/70 and 80/100	Painting, premixing and seal coats.
(5) 80/200	Surface dressings and in very cold climates.

23. Hot Process Products

Name	Company	Temperture required	Penetration at 77°F/25°C	Details
1. Maxphalt	Burmah Shell	350—375	20/30 to 80/100	Surface painting and premix and Seal Coats
2. Spranese	Burmah Shell	350—375	180/200	Surface dressing and premixed carpets
3. Stanvac paving	Standard Vacuum Oil Co.	350—375	30/40—100/120	Grouting, premixing, surface painting.
4. Hot mix	Mcleod Co.	370—400 or 350—370	20/40—80/100 40	Surface painting, premixing and Seal Coats. premixing.

23A. Choice between premix macadam and full grout.

Premix macadam requires much less bituminous material and the aggregate can be uniformly coated. It is cheaper than grout but it is found that it cannot carry heavy bullock cart traffic. For motor vehicles the surface is satisfactory. Full grout is more costly than premixed and is superior in following points :

(*i*) The relatively thicker film between the metal and chips, makes the pavement resilient and durable.

(*ii*) The action of water does not strip the bitumen from silicious stone.

(*iii*) Carrying capacity is greater, especially where iron-tyred bullock carts are to be catered for.

24. Cut Backs.

1. Shelspra B.S.	Burmah Shell.	325—340	300/350	Surface painting, premixing (Low viscosity).
2. Shelmac B.S.	Burmah Shell.	275—300	120/150	Premixing.
3. Shelmac R.C.	Burmah Shell.	Cold application.		Surface dressing & premixing.
4. Shelmac D.	Burmah Shell.	275—300	120/150	Surface dressing & premixing.
5. Socofix.	Standard Vacuum Oil Co.	Cold application.		Thin carpets & patch work.
6. Socosol.	Standard Vacuum Oil Co.	Cold solvent in hot asphalts mixed 11% by weight.		For thinning out or retarding setting hot asphalts.

25. Emulsions (Cold Process Products)

Name	Company	Details
1. Colas	Burmah Shell	Surface painting and grouting to be damped by water before use.
2. Colas mix	Burmah Shell	Premixing carpets.
3. Stanvac Emulsion No. 3	Standard Vacuum Oil Co.	Surface painting.
4. Stanvac Emulsion No. 6	Standard Vacuum Oil Co.	Premixing carpet up to 1½" thickness, semigrout, seal coats, wet weather repairs.
5. Colfix	Mcleod and Co.	Surface painting, premixing, seal coat repairing pot holes.

26. Primers.

Name	Company	Application Temperature	Details
1. Shell primer No. 1	Burmah Shell	150	Surfacing for open textured roads.
2. Shell primer No. 2	Burmah Shell	100 or sun warmed	Priming purposes.
3. Socofix primer	Standard Vacuum Oil Co.	Cold application.	Priming or water proofing
4. Liquid Asphalt No. 2	Standard Vacuum Oil Co.	Cold application cut back asphalt	Dust laying, lowcast paintlng

27. Grouting.

Inches	Hot Binder Lbs	Emulsion	Stone	Remarks.
3″	165—190	—	30	Blindage not included.
2″	110—140	165 lbs	20	Penetration of asphalt.
Semi grouting	45	85	20	30/40. Heated to 350° to 375° F (Tar No. 3 A)

28. Binder. (*i*) Tar 4 lb/cft for metal of 1″ size and above (high viscosity Tar)

(*ii*) Tar 5 lbs/cft for 3/8″ metal and above (Tar No. 3 A)

(*iii*) Tar 7 lbs/cft. for sand (high viscosity Tar)

Bitumen :—	1½" to 1" metal	2½ to 3 lbs/cft
	3/4" to 1/2" metal	3—3½ lbs/cft
	3/8" to 1/4"	3½—4 lbs/cft
	3/4" to 3/8"	4—6 lbs/cft

30. Hot Bitumens (30/40 penetration) cut backs Emulsion.

Passing mesh	Retained mesh	Lbs/cft
10	40	4—6
40	80	6—8
80	200	8—10
200	—	10—15

Add 2% for wastage.

Cut backs and emulsions are not used per carpets more than 1" or 1½" thick.

30A. Gang for Rolling and Resurfacing.

9000 square yards or 81000 sq. ft. can be rolled each day.

Thickness of metal 2".

Labour :—

Picking	35 men
Metal filling	8 men
Metal carrying 12 women	12 women
Sectioning	6 men
Spreading blindage	6 women 400 cft.
Brushing	6 men

31. Bituminous Carpets.

Metal size	Thickness											
	2½″		2″		1½″		1″		¾″		½″	
1½″	8			10								
1″		20		6		8						Sand Carpet
¾″			16			4	7		5			
½″					12			5½	3	6		
⅜″							3			2		
Sand	10	10	8	8	6	6	3	5½	4	2	8	5
Binder	130	140	115	110	90	85	65	63	58	54	64	40

32. Base Course open textured

Size Metal	Thickness of carpet										Remarks
	3″	2½″		2″		1½″	1″		3/4″		
2″		16									Add 5% of chippings 2½% of binder.
1½″	22		18		12						
1″	8	8	7	15	—	12					
3/4″	—	—	—	5	6	4	—	6			
1/2″	—	—	—	—	—	—	10	—	7	6	
3/8″	—	—	—	—	—	—	—	4			
1/4″	—	—	—	—	—	—	—	—	—	2	
Filler	120	96	100	80	72	64	40	40	25	25	
Binder	90	64	66	60	56	50	40	35	25	26	

33. Quantities of metal required for patch 12 ft. wide per mile.

1. Light traffic 700 to 900 c. ft.
2. Medium Traffic 1000 to 1500 c.ft.
3. Heavy traffic 2000 to 4000 c.ft.

34. For porfroms on gradients add 5% more.

Norminal size of chippings (Inches)	Quantity of tar spread	
	Hand broken sq. yd./gallon	Crushed sq yd./gallon.
3/4	5	4·5
½"	5 5	4·5
3/8	6·5	5·5
1/4"	7·5	7·5

35. 1st Dressing (Tar macadam)

Chippings	Water bound macadam well bounded	Tar macadam (open textured
3/8"	4	4·25

35-A. Viscosity : Property which retards flow so that greater the viscosity the lower or slower is flow of inqured. Tested with viscometer.

Ductility : It is a binding quality and adhesiveness. If less, the road will crack.

Specific gravity : Asphat has 1 to 1·02 gravity, cut back 0·93 to 0·98 and Emnlsion nearly One. Generally taken as one gallon to 10 lbs of asphatic (Bitumen Tar)

36. British Tar Association.

Chippings	sq. yds. /ton	Remarks.
3/4"	70—80	Small metal not to weigh less them 78 lbs per c. ft.
1/2"	90—100	
3/8"	100—120	
1/4"	140—170	

37. Surface dressing of roads with Tar (SHALIMAR TAR)

Mode of traffic	Quantity of Tar/100 sq. ft. of road (Lbs.)	TAR No.	Quantity of Metal/100 sq.-ft. of road (C. ft.)	Size of metal	Remarks
		1st COAT		By volume	
Light	38	3	5	3/4"—2 parts 3/8"—1 part	For Carpet surface
Heavy	43	3A	6	Do.	
Light	42	3A	5	Do.	
Heavy	53	3A	6	Do.	
		2nd COAT			
Light	28	3	4·0	1/2"—2 parts 1/4"—1 part	
Heavy	33	3A	4·5	3/4"—2 parts 3/8"—1 part	
		Stabilizing coat with sand			
Light	32		2·5	Medium sand	
Heavy	38		2·5	Do.	

Add 2½% for wastage of tar and 5% of metal. Tar is heated to the following : No. 3—200° to 220°F
No. 3A—220° to 240°F

38. Classification of Roads (I.R.C.)

		Width of Land required
National Highways	...	150 ft.
Provincial Highways	...	100 ,,
District Roads	...	66 ,,
Village Roads	...	25 ,,

39. Width of Pavements. (I.R.C.)

12 ft. (Single lane)

22 ft. (Double lane) plus 5 ft. berm on each side.

Width of pavement of level crossing, approach roads upto 100 ft. measured outwards from gates.

22 ft. Single lane.
32 ft. Double lane.

40. Surface Dressing.

Bitumen	Quantity of Bitumen/100 sq.ft. of road surface	Quantity of metal/100 sq.ft. of road surface	Size of metal	Remarks
Quality	Lbs.	C. ft.	Inch	
	One Coat			
Hot 80/100	40	4·5	½"	Heavy traffic
	Two Coats			
	25	First Coat 6·5	½"	2nd coat to b applied im mediately.
	45	Second Coat 3·5	½" and less	

	Renewal Coat			
	25	3·75	¼″ and less	To be applied cold also on wet surface chippings to be spread before colas has broken and turned from brown to black.
	Two Coats	(1st Coat)		
EMULSIONS	38	4·5	½″	
		(2nd Coat)		
	28	3·5	¼″ and fine	
	Renewals			
	30	3·5	¼″ to fine	

Add 2·5% wastage for Bitumen and 5% wastage of metal.

40-A. Difference Between Tar and Bitumen.

(*i*) Tar is more snsceptible to temperature changes than bitumen.

(*ii*) Tar can be brought to spraying condition at lower temperature than bitumen.

(*iii*) Surface dressing with tar is not ⌋ easily prove to failure by water displacement than bitnmen.

(*iv*) Tar makes harder surface than bitumen.

(*v*) Tar has higher specitic gravity and lower viscosity than bitumen.

(*vi*) Tar has more penetrating power than bitumen.

(*vii*) Volume of tar requiied is 10% more than bitumen.

(*viii*) Bitumen gives better results then fluxed with tar oils.

41. Seal Coats (for 1 o sq. ft.)

Binder		*Metal*		*Remarks*
Type	Quantity Lbs.	Size	Quantity Lbs.	
Hot Asphalt 80/100	25—30	¼—3/8 or Sand	3·5—4	Grouted or semi-grouted
	15—20	,,	3·5	Lighter application
Cutbacks	30	¼	5	Pre-mixed surface
	20	sand	2·5—3	Lighter application
Cold Emulsions	40	¼	3·5	Grouted or semi-grouted
	20	¼	4	Premixed surface
	15	sand	2	Lighter application
Tar	18	sand	2	Lighter application

Add 5% for wastage of metal 2·5% of binder.

42. Repairs.

(*i*) Pot holes—Dry weather. (Cold process)

(*a*) Socofix for 100 sq. ft. ... 35 lbs.

(*b*) Metal ½" ... 5 cft.

¼" to 3/8" ... 2 cft.

Or

(*i*) Asphalt with metal at 3 lbs/cft. of 1½" metal and 3¾ lbs. per ¾" to ½" size metal.

Sand for Binding.
For 100 cft. of patching.

		Asphalt.
Metal 1½ to 1″	50 cft.	150 lbs.
¾″ to ¼″	50 cft.	180 lbs.

(*ii*) Repairs to pot holes (Rainy season) (Cold way) 100 cft.

(*a*) Sand for blindiug.
(*b*) Metal 1½″ to 1″ 50 cft. 250 lbs. Binder
¾″ to ¼″ 50 cft. 375 lbs.

(*iii*) Pot holes (Hot process) 100 ft.

(*a*) Sand for Binding.
(*b*) Metal.

(b1) 1½″ to 1″ 50 cft.
(b2) ¾″ to ¼″ 50 cft.

(*c*) Binder 30/40 or 80/100+Socosol.

(b1) 150 lbs.
(b2) 180 lbs.

43. Materials required for black topping.

(1) Wire Brushes.
(2) Brass broom.
(3) Pouring cans.
(4) Measuring boxes.
(5) Buckets.
(6) Screens.
(7) Spring balance.
(8) Wooden forms.
(9) Hand picks.
(10) Gunny bags.
(11) Camber Board.
(12) Tamper.

Rolling should always proceed in longitudinal direction beginning at outer edge and working towards centre. Each trip overlapping the previous trip by about ½ the width of the rear wheel. Speed of the Roller to be as slow as possible to prevent any pushing under the wheels.

44. Cement Concrete Roads.

Proportion	*Quantity of Cement*	*Quantity of sand per bag of cement*	*Quantity of metal per bag of cement*
1 : 2 : 4	Ordinary cement 1 bag=110½ lbs	2·4 cft. water 6 gallons	4·8 cft.
1 : 2 : 4	Rapid hardening cement 1 bag=110½ lbs.	2·8 cft. water 7 gallons	5·6 cft.

45. Mile and Furlong Stones and Road signs.

(*i*) *Mile and Furlong stones 5' to 8' away from edge of road.* On left hand side letters $2\frac{1}{2}'' \times \frac{1}{2}''$. Information on mile stones as below :—

(*a*) Milage to next large town

(*b*) On top chamfer milage to point of origin in case of highway roads.

(*ii*) *Road signs.*

(*a*) Curves and corners.
(*b*) Schools
(*c*) Causeways
(*d*) Bridges and Crossings
(*e*) Main crossings
(*f*) Road junctions
(*g*) Ghats
(*h*) Guard stones
(*i*) Kerb stones
(*j*) Wheel guard stones.

Note. (*i*) All warning signs should be 300 to 400 ft. away from the point of danger at a place where it is quite visible to drivers.

(*ii*) Size of plate 18" wide 15" high or danger Red triangle $18'' \times 18''$ with red border circular 2 ft. dia Centre of the sign plate 10 ft. above ground level on $3'' \times 3'' \times 3/8''$ 'T' iron, 2 ft. inside ground, 6 ft. above road surface.

CHAPTER I

Bridges and Culverts

(1) **Indian Road Congress Recommends Crossings· Classifications.**

(*i*) Classes.

(*a*) Class AA :— Heavy loading, Adopted only in industrial areas or important areas of highways.

(*b*) Class A :— Standard loading to be used for general permanent structures.

(*c*) Class B :— Temporary structures 60% of class A.

(*ii*) Approaches :— The approaches on both the side of crossing should be more than 100 ft. straight length, but in no case less than 50 ft. in case of bridges and 20 ft. for culverts etc. Slopes should not exceed 1 in 30 gradient.

(*iii*) Parapets :— Culverts 1 ft. high minimum 13½″ thick. Bridges, 3·5 to 4 ft. high and 1½′ thick.

These must be protected by wheel guards and kerbs on both the side of crossings.

(*iv*) Railing :— Hand rails should be of angle iron of 2″ width (Min) 6 ft. apart with G. I. Pipes of 1″ dia.

(*v*) Wheel guards :— 6″ to 9″ high above the adjacent road surface 9″ wide.

(*vi*) Kerb stones :— Not less than 2 ft. wide 9″ to 1′ high.

(*vii*) Width of crossings :— (*a*) 12 ft. single lane clear.

(*b*) 22 ft. for double lane clear.

Width for parapets to be extra.

(*viii*) Free Board :— Free board for high level bridges should not be less than 2 ft.

(*ix*) *I. R. C. Bridge coat vertical clearance.*

Discharge cusecs.		Vertical clearance.
Below 10	...	6″
10—100	...	1′
100—1000	...	2′
1000—10,000	...	3′

(*x*) *Cross Sections.*

Catchment area.	...	Distance upstream and downstream
One mile or less	...	500 ft.
From 1 to 5 sq. miles	...	1000 ft.
Over 5 sq. miles	...	¼ mile to 1 mile.

2. Foundations. (I. R. C. Code. H. F. L. = 1·33 D)

D = Crodible Strata depth.

(*a*) Small bridges height on dry land. Sufficiently solid, a depth 5 to 6 ft.

(*b*) Formulae :— d = depth of founds.

d' = depth of scour

R = hydraulic mean depth.

(*i*) Average sites $d = 1{\cdot}6\ d'$ or 2·5 R.

(*ii*) Bad sites $d = 2{\cdot}1d'$ or 4·0 R.

(*iii*) Torrential beds of boulders shingle etc.

$d = 2d''$ for culverts and causeways.

$d = 3d''$ for bridges.

Larger of the two values to be adopted.

CHAPTER II

1. Water ways and Catchment Areas.

(Dun Drainage Table.)

Catchment area in sq. mile	Area of waterway in sq. ft.			
		In Hills	In Plain	
	120%	100%	80%	50%
0·5	60	50	40	25
1·0	120	100	80	50
5·0	600	500	400	250
10·0	815	679	543	340
50·0	1882	1510	1208	755
100·0	2554	2120	1696	1060
200·0	3564	2970	2376	1845
500·0	5532	4610	3638	2305
600 0	6036	5030	4024	2505
800·0	6969	5800	4640	2900
900·0	7296	6080	4864	3030
1000·0	7656	6380	5104	3190

2. Abutments and Piers (I. R. C. and M. E. S.)

Height of Abutment	Earth Cushion	Span	Top	Pier-Top.	Length of pier = 1½ times top width.
5	5 0′	10	1·9′	13½″	Pier batter = 1 in 30
10	4 0′	15	2·3′	18″	Depth of pier = 1·6 × 2·5 × H.F.L.
15	3·0′	20	2·5′	22″	
20	2·0′	30	2·7′	26″	Width of pier = 1/8th of total height.

3. **Skew Bridges.** As far as possible skew bridges should be avoided and should not be sharper than 60°.

4. I. R. C. Class A Loading

Axle load	Wheel load	Length of contact at rt. angle to the axle in inches.	Width of tyre.
25000 lbs	12500 lbs	10″	20″
15000 lbs	7500 lbs	5″	15″
6000 lbs	3000 lbs	6″	8″

(5) Clear Distances.

Clear Road Width	Min. clear distance between the adjacent edges of wheels on bridges.	Minimum clear distance between road ways face of kerb and outer edge of wheel.
18′	1′—4″	0′—6″
18′ to 24′	Gradually increasing from 1′—4″ to 4′-0″.	0′—6″
Above 24′	4′—0″	0′—6″

Minimum Poad width 22′—0″, between the adjacent edges of the wheels of passing or crossing vehicles is 3′—1″.

6. Loading of Culverts.

Span up to 5 ft.	Thickness of arch 9″
6′ to 5 ft.	13½″
11′ to 18 ft.	1′—6″

6. (a) Design of Culvert (Talbot Formula)

Area of Culvert section in sq. ft. $= a = CA^n$

C = coefficient depending on climates topography and size of area.

A = the catchment area in Acres

n = constant varying 0·5 to 0·8

Talbot gave $n = 0{\cdot}75$

Flat area $c = 0{\cdot}2$

Evenvalleys $c = 0{\cdot}33$, nneven land C = 0·5, moderaet slope C = 0·66, steep slopes C = 1·00.

Span in Ft.	2	3	4	5	6	8	10	15	20	25	30	35	40
t_1	8″	9″	1′	1′	1′	1′	1′	1′—3″	1′—6″	1′—8″	1′—9″	1′-10″	2′—0″
t_2	9″	1′—1½″	1′—1½″	1′—1½″	1′—1½″	1′—1½″	1′—1½″	1′—6″	1′-10½″	1′-10½″	2′—3″	2′—3″	2′—7½″
t_3	9″	9″	1′—1½″	1′—1½″	1′—1½″	1′—1½″	1′—1½″	1′—6″	1′—10″	1′-10½″	2′—3″	2′—7½″	3′—0″	3′—4″
C	1′—6″	1′—6″	1′—6″	1′—6″	1′—6″	1′—6″	2′—0″	2′—0″	2′—0″	2′—0″	2′—0″	2′—0″	2′—0″
E_1	2′—6″	2′—0″	2′—6″	2′—9″	3′—0″	3′—3″	3′—6″	4′—3″	5′—0″	5′—9″	6′—6″	7′—3″	8′—0″
E_2	2′—3″	2′—3″	2′—7½″	2′—7½″	3′—0″	3′—4½″	3′—9″	4′—6″	5′—3″	6′—0″	6′—9″	7′—9″	8′—3″
P_1	1′—4″	1′—4″	1′—8″	1′—10″	2′—0″	2′—3″	2′—6″	2′—9″	3′—3″	3′—9″	4′—3″	5′—0″	5′—9″
P_2	1′—6″	1′—6″	1′ 10½″	2′—3″	2′—3″	2′—3″	2′—7½″	3′—0″	3′—4½″	4′—1½″	4′—6″	5′—3″	6′—0″
P_3	1′—6″	1′—6″	1′-10½″	2′—3″	2′—3″	2′—7½″	3′—0″	3′—4½″	3′—9″	4′—1½″	4′—6″	5′—3″	6′—0″
G_1	1′—0″	1′—0″	1′—0″	1′—3″	1′—3″	1′—6″	1′—6″	1′—9″	2′—9″	2′—0″	2′—6″	2′—6″	2′—6″
G_2	1′—6″	1′—6″	1′—6″	1′—9″	1′—9″	2′—0″	2′—0″	2′—6″	2′—9″	3′—0″	3′—3″	3′—6″	3′—6″

t_1 = 1st class stone, concrete Block masonry 1 : 3 cement mortar.

t_2 = 1st class masonry Brick work cement mortar 1 : 3.

t_3 = 1st class Brick work in lime mortar 1 : 2.

C = coarse stone masonry in cement mortar 1 : 3.

E_1 = 1st class stone masonry in 1 : 3 cement mortar.

E_2 = 1st class brick masonry in cement mortar 1 : 3.

P_1 = 1st class brick masonry in cement mortar 1 : 3.

P_2 = 1st class brick masonry in 1 : 3 cement mortar.

P_2 = 1st class brick masonry in 1 : 3 cement mortar.

G_1 = P. C. Concrete 1 : 3 : 6.

G_2 = P. C. Concrete 1 : 4 : 8.

2. Pipe Culverts.

Diameter	Thickness of Shell				
	Masonry	Cement Concrete	R. C. Concrete	Hoop Bars	Longitudinal Bars
12	4½″	3″	—	—	—
24	9″	4″	2½″	1/4″@4″c.c.	1/4″@9″c c.
36	9″	5″	3″	3/8″@5″c.c.	—
48	9″	6″	3½″	3/8″@4″c.c.	
60	13½″	7″	4½″	1/2″@5″c.c.	
72	13½″	8″	5″	1/2″@4″c.c.	

3. R. C.C. Slab with 3" wearing Coat.

Freely supported (I. R.C. Standard Class A)
Longitudinal reinforcement may be bent in every 4 ft. up to 10 ft. span in every two for above 10ft.

Clear Span Ft.	B.M./f width t 1000 in L.B.S	Shear per Ft. width L.B.S.	Total thickess of stop exclu- ding wear coat.	Concrete below centre of steel.	Ite in for cement			
					Main		Distribution	
					Dia of bar	Spacing C.to C. Inches	Dia of bar Inches	Spacing C. to C. Inches
3	34	3970	7"		3/8"	3½"	3/8"	7"
4	46	4440	7½"		1/2"	4½"	1/2"	9½"
5	56	4520	8"		1/2"	4"	1/2"	9½"
6	93	5670	9½"		1/2"	3"	1/2"	8½"
7	113	6050	10"	1¼"	5/8"	4½"	1/2"	7½"
8	138	6250	11"		5/8"	4"	1/2"	7½"
9	159	6590	11½"		3/4"	5½"	1/2"	7½"
10	190	6660	12½"		3/4"	4½"	5/8"	11"
12	250	7210	14½"		3/4"	4½"	5/8"	10½"
14	320	7630	16"		3/4"	3½"	5/8"	10"
15	357	7860	17"		1"	6½"	5/8"	10"
16	394	8160	17½"		1"	6"	5/8"	9½"
18	474	8630	19½"		1"	5½"	5/8"	9½"
20	567	9260	21"		1"	5'/	5/8"	9"
22	662	9760	22½"	1½"	1"	4½"	3/4"	8½"
24	755	10380	24"		1"	4½"	3/4"	12"
25	850	10750	25"		1"	4"	3/4"	12"
27	961	11520	26½"		1"	3½"	3/4"	11"
30	1190	12880	29½"		1"	3½"	3/4"	10"

4. R. C. C. Slab with 3" Wearing Coat.

Freely Supported (I. R. C.)

ear ban	Slab	Concrete cover below Steel	Re-inforcement			
			Main		Distribution	
			Dia. of Bars	Spacing c/c	Dia of Bars	Spacing c/c
Ft.	Inches	Inches	Inches	Inches	Inches	Inches
2′	5″	1½″	3/8″	3½″	3″	8″
3′	5½″		3/8″	3″	3″	7″
4′	6″		1/2″	5″	3″	7″
5′	6″		1/2″	4½″	1/2″	10″
6′	6½″		1/2″	4″	1/2″	9½″
7′	7″		5/8″	5½″	1/2″	9″
8′	8″		5/8″	5″	1/2″	8½″
9′	8½″		5/8″	6½″	1/2″	8″
0′	9″		3/4″	6½″	5/8″	12″
2′	10″		3/4″	5½″	5/8″	12″
4′	11½″		3/4″	4½″	5/8″	11″
5′	12″	2½″	3/4″	4½″	5/8″	11″
6′	12½″		1″	7½″	5/8″	10½″
8′	14″		1″	6½″	5/8″	10″
0′	16″		1″	6″	5/8″	10″

Note :—Load 12 tons Roller plus impact.

CHAPTER IV

Bridges and Culverts

1. I. R. C. Beams for Bridges

Clear span 15	16—17	18—19	20 23	24—26	27—30
Size of R. S. Beam inch lbs. 15×6×45	16×6 ×50	18×6 ×55	20×6.5 ×55	22×7 ×75	24×7 5 ×90

(*a*) R. S. Beams are 5′—6″ apart.

(*b*) R. C. C. slab Decking slab 6″ av. thick. Reinforcement ½″ bars. 5″ c c. at rt. angles to direction of beams. Adequate reinforcement at top of slab over beam for pos B. M. longitudinal bars (temp) at bottom of slab ½″ dia 8″ c. c. and top ½″ dia. at 1½″ c.c. should be provided.

(*c*) M. S. Plate (Bed 3/8″ thick be provided in two layers of 1/8″ thick load sheets under beams.

(*d*) Decking slab will be 6″ plus width of parapet on both sides of the end beam to make up 12′ traffic lane.

(*e*) 1″/100 ft. for expantion of girders.

(*f*) 3/4″ dia anchor bolts in slotted holes. Two bolts for each end.

(*g*) Bottom of R C. slab either rests on top of beams or is made level with the bottom side of top flange and bars rest on the beams.

(*h*) 2½″×2½″×¼″ L spacer is fixed @ centre at right angles to girder in pos above 20′.

(*i*) *Drainage holes to be on both sides of Road at 8 ft. intervals.*

2. Corrugated galvanized pipes culverts (Armco Pipes)

Dia.	Length of sheet before forming.	Min Width of lap	Sheet Gauge No.
8″	28½″	1½″	16
10″	35″	1½″	16
12″	41″	1½″	16
15″	50½″	1½″	16
18″	60″	1½″	16
21″	69½″	1½″	16
24″	80″	2″	14
30″	98″	2″	14
36″	117″	2″	12
42″	137″	3″	12
48″	156″	3″	12
64″	2′-80″	3″	12
60″	2′-98″	3″	10

3. Rivets

Gauge No.	16	14	12	10	8
Dia. inches	5/16	5/16	3/8	3/8	3/8

CHAPTER I

Irrigation and Hydraulics

1. Line of Saturation.

(*a*) Good compact soil	... 1 in 4
(*b*) Average soil	... 1 in 5
(*c*) Bad soil	... 1 in 6
(*d*) Fine silt	... 1 in 6
(*e*) Fine sand	... 1 in 8
(*f*) Coarse sand	... 1 in 10

2. Safe Velocities in Channels.

(*a*) Clay	... 0·75 ft/second
(*b*) Sandy soil	... 0·75 to 1·00
(*c*) Sand	... 1·00 to 1·50
(*d*) Coarse sand	... 1·50 to 2·00

3. Velocity. 2 to 3 ft. (with 1½ ft. min) per second will prevent the deposit of silt or growth of grass.

D is depth of water. Vo=is critical velocity in foot/second.

D	Vo	D	Vo	D	Vo
1	0·84	6	2·64	12	4·12
2	1·30	7	2·92	15	4·75
3	1·70	8	3·80	20	5·71
4	2 04	9	3·43	50	10·27
5	2·35	10	3·66	100	16·0

4. Hydraulic mean depth.

There is scour in a channel of Hydraulic mean depth in ft.	Until a mean velocity is reached.					
	Foot per second.					
	Fine silt	Heavy silt and fine sand	Coarse Sand	Pebbles and gravel	Large pebbles and coarse sand	Stones
1·0	0·4	0·9	0·75	2·25	5·0	15·0
2·5	0·7	1·5	2·25	3·0	6 0	—
5·0	0·9	1·75	3·0	3·5	7·0	—
10·0	1·5	2·25	3 5	4·5	9·0	23·0

5. Velocity in Channels.

(*a*)

Canal main	3½ ft/second
Branch canals	3 ft/second
Distributaries (large)	2½ ft/second
Distributaries (small)	2 ft/second
Distributaries (Minor) watercourses and field drains	1 to ½ ft/second.

(*b*)

Ft. per second	Materials
0·25	Soft clay, fine clay, river mud, or silt.
0·50	Common clay.
0·70	Fine sand.
0·80	Coarser sand.
1·00	Fine gravel and coarse sand.
2·00	Pebbles 1" dia.

3·00 to 3·33	Pebbles 1½″ to 2½″ dia.
5·00	Stones 3″ diameter.
6·60	Boulder 6″ to 8″ dia.
10·0	Boulders 12″ to 18″ dia.

(c) Mean velocities of Erode channels.

Material of channel bed.	Velocity in ft/sec.	
	Shallow ditch	Deep canal
Fine sand or silt	0·50—1·50	1·50—2·50
Coarse sand or sandy loam	1·00—1·50	1·75—2·50
Silty or sand loam	1·00—1·75	2·00—3·00
Clayey loam or sandy clay	1·50—2·00	2·25—3·50
Fine gravel	2·00—2·50	2·50—5·00
Well graded gravel	2·25—3·50	4·00—6·00
Pebbles, broken stones	2·50—4·00	5·00—6·50
Stone masonry	7·60—15·00	——
Solid rock or concrete	15·00—25·00	——

6. Critical Velocity ratio.

Vo is not constant but varies with depth of channel. In case of small channels, the greater the water depth the steeper can be the bed slope. When depth is fixed bed can be widened and depth decreased.

7. Side slopes.

Ratio of slope—Horizontal to vertical.

½ : 1	...	soft rock, hard moorum
1 : 1	...	soft moorum
1½ : 1	...	gravel

$1\frac{1}{2} : 1$	... ordinary earth, dry sand.
$2 : 1$	... loose earth.
$2\frac{1}{2} : 1$	... wet sand.
$3 : 1$	... wet clay.

8. Curves in channels.

Capacity of channel			Min. radii.
Below	10 cusecs	...	300 ft
	10 to 100	...	500 ft
	100 to 500	...	1000 ft
	500 to 1000	...	2000 ft
	1000 to 3000	...	3000 ft
Above	3000 cusecs	...	5000 ft.

In general min. radius 20 times the bed width of the canal.

9. Width of Bank.

Channel up to 49 cusecs	4 ft
50 to 99	5 ft
100 to 200	6 ft
200 to 300	8 ft.

10. Earthen Dams.

Proportion of materials making water-proof dam.

(1) Coarse gravel	59%	
(2) Fine gravel	20%	Layer not to exceed 9" and
(3) Sand	9%	consolidated with Roller.
(4) Clay	12%	

11. Theoretical velocity in respect to the head of water or pressure is taken.

$V = \sqrt{2gH}$ $= 8{\cdot}025\sqrt{H}$

$1/2g = 0{\cdot}0155$ $H = V2\sqrt{2g} = 0{\cdot}0155V^2$

=the head of energy required to produce a velocity of V ft. per second. It is also called velocity head.

V=velocity in ft. per second.

H=head of water in feet.

g=accelaration or gravity constant.

=32·2 ft/sec. Hydraulic mean radius or Hydraulic mean

$$\text{depth} = \frac{\text{Cross section area.}}{\text{Wetted perimeter}} = R$$

$$\text{Sine of slope} = \frac{\text{Fall}}{\text{Length}} = S$$

1 H. P.=33,000 lbs raised if high in minute

=550 lbs raised 1 ft high in 1 second.

Power exerted by 8·8 cft water falling if in 1 second.

11. Water Pressure.

$$P = \frac{Wh^2}{z} = \cdot 433\ h$$

or $$h = 2 \cdot 307\ P$$

W = Wt. of cft. of water

= 62·4 lbs.

h = ht. of water.

12. (i) Discharge through Notches.

$$Q = 2/3\ CB\sqrt{2g}\ H^{3/2}$$

Q = Discharge/Sec. in cft.

C = Co-efficient of discharge

C = 60 to 62 for sharp plate wiers

A = Area in sq. ft. = BH

(ii) Triangular Notches.

$$Q = 4/15\ CB\sqrt{2g}\ H^{3/2}$$

(*iii*) **Notch with right angle.**

$$Q = 8/15\ C = \sqrt{2h}\ H^{5/2} = 2{\cdot}54H^{5/2}$$

H = Ht. above bottom of notch in inches.

13. Orifice.

$$Q = CA\sqrt{2g}\,H$$

$$= 5A\sqrt{H} \text{ sharp edge orifice}$$

$$Q = 0{\cdot}97A\sqrt{2gH} \text{ Bell mouthed orifice}$$

$$Q = 2/3CB\sqrt{2g}\,(H^{3/2} - H1^{3/2}$$

Large vertical orifice with small head.

14. Partially submerged.

Q1 = Rectangular orifice of depth H2—H1 and Q2 = through a submerged orifice of head H2.

(*i*) *Discharge through free portion* (*Like notch*)

$$Q1 = 2/3\ CB\sqrt{2g}\ (H2^{3/2} - H1^{3/2})$$

B = Breadth of wier.

(*ii*) *Discharge of water into water.*

$$Q2 = CB\sqrt{2g}\,H^{\frac{1}{2}}$$

Total discharge will be Q1 + Q2

15. Wiers.

$$Q = 2/3\ CB\sqrt{2g}\,H^{3/2}$$

Sharp crest wier and Trapezoidal wier.

Bazins Formula of rectangular wiers.

$$Q = 2/3C\sqrt{2g}$$

$$BH^{3/2} = M\sqrt{2g}\,H^{3/2}$$

$$M = 0{\cdot}405 + \frac{{\cdot}00994}{H}$$

16. Rise of water caused by wier.

$$H = \frac{3\sqrt{Q^2}}{\sqrt{11B^2}}$$

B = Breadth of wier.

17. Discharge over broad crested wier.

$$H = h + \frac{V_2}{2g}$$

Max. discharge when

$h = 2/3H$ in that case,

$$Q = 3{\cdot}09\ BH^{3/2}$$

18. Rounded crested wier:

$$Q = C_1\ BH^{3/2}$$

C_1 = 3 to 4·5 according to crest.

19. OGEE shaped wier.

$$Q = 4{\cdot}2\ BH^{3/2}$$

20. Siphon spill way.

$$Q = CA\sqrt{2g}\ H$$

C = 0·75

A = Area of siphon spill openings.

H = Difference in levels of water up stream and down stream.

21. Kutter's Formulae.

$$V = C\sqrt{RS} \qquad C = \frac{a + \frac{L}{n} + \frac{M}{S}}{1 + \left(a + \frac{M}{S}\right)\frac{n}{R}}$$

a = 4·66
L = 1·81
M = ·0028

Volume of n = (*i*) 0·010 glazed pipes, smooth iron pipse and smooth cement work.

(*ii*) 0·011 cement plaster.

(*iii*) 0·013 brick work.

(*iv*) 0·015 cast iron and stone work.

(*v*) 0·025 canals, rivers in earth.

(*vi*) 0·050 torrential rivers.

22. Bazins Formulae.

$$V = C\sqrt{RS}$$

$$C = \frac{157{\cdot}5}{1+\sqrt{R^6}}$$

23. Chezy's Formulae.

$$V = C\sqrt{RS}$$

C = 0·109 Glazed and smooth surfaces.

0·35 Concrete and brick work.

0·83 Rubble

1·54 Newly dressed earth work.

2·36 Earthen Rivers and Channels.

3·17 Rough earthen canals.

24. Mannings Formulae.

$$V = \frac{1{\cdot}486}{n} \times R^{2/3} \times S^{1/2}$$

25. Velocities to move Stones—Chailys Formulae.

$$V = 5{\cdot}67\sqrt{G.d}$$

or $$d = \frac{V2}{85}$$

d = Diameter of stones in ft.

G = Specific gravity of stone.

V	1/2	1	2	3	4	5	7	10	15	20	25	30	35	40
d	1/28″	1/7″	5/8″	1¼″	2½″	3½″	7″	1·2′	2·7′	4·7′	7·4′	10·6′	14·4′	15·6′

CHAPTER 1

Electrification

Danger :— Voltage 250 or less is low pressure.

250 to 650 medium and above high pressure.

D. C. (Direct current) is dangerous than A. C. (Alternating current). Safe voltage for dry hands is 30 and for wet 22·5 volts.

1. Institution of Electrical Engineers Regulations.

System of wiring :— The wiring must be done on distribution system with main and branch distribution Boards at convenient centres and without isolating fuses. Conductors to run along walls and ceilings.

(B) Conductors :— All conductors to be of copper in accordance with B.S.S. or I.E.E. regulations, cross section not less than 0·0015 sq" or 0·002 sq".

(C) Switches :— All switches be iron clad type.

(D) Control at point of entry of supply :—There shall be only one switch and one main fuse for each pole of each main circuit at point of entry of supply.

(E) Distribution boards shall be in clad type with appropriate No. of ways and controlled as specified.

(F) One spare circuit may be provided on each main and branch distribution board and each final sub-circuit shall be connected not more than 8 points or a connected load of 5 watts whichever is less. Every fan, light or plug point shall be treated as a point for this purpose.

(G) Switches and Fuses of opposite polarity shall be mounted on separate basis and holes for fixing bolts of basis shall be bushed.

(H) The lead shall be evenly balanced between the various ways.

(I) In the construction and fixing of main and branch distribution boards the following requirements shall be fulfilled :—

(*i*) All the fuses shall be of approved type and two spare fuses carriers are to be for each main and Branch distribution boards for replacement.

(*ii*) Connections of all circuits carrying more than 10 amps shall be made by means of cable sockets.

(*iii*) All boards other than those of iron clad pattern shall be strongly made. Well finished and approved teak wood case with devetailed corners and shall be varnished or polished.

(*iv*) Except in case of iron clad boards cases shall have hinged or sliding plate-glass doors with glass not less than 1/8th inch thickness and the door shall be capable of being short when any switch is either "ON" or "OFF".

2. Passing Through Walls.

(*i*) Conductors shall be carried in heavy gauge conduits, or porcelain tube and the ends of the conduits or porcelain tube shall extend an inch beyond the wall straight and to be flush with wall if the course of wires is at right angles, to the wall. The ends of the conduit or pipe shall be neatly arranged to be fitted in with the type of wiring used.

(*ii*) Where a wall tube passes outside a building so as to be exposed to the weather, the outer end shall be bell mouthed and turned downwards.

3. Plugging Walls.

Plugs for ordinary walls or ceiling shall be of well seasoned teak, not less than 2" long by 1". Square on the inner end and 3/4" square on the out end. They shall be cemented into the walls to within $\frac{1}{4}$" of the surface use with plaster or lime.

4. Wall Sockets.

Wall socket shall be provided of approved quality for ordinary two pin plugs and three pin power plugs. The points to be controlled by a switch of adequate capacity and the switch shall be on the 'Live" side. The sockets shall be

fixed in general adjacent to, on, or below the Board where the control switches etc. for individual points are fixed.

5. Fittings.

Where conductors require to be threaded, through tube or channels formed in the metal work of fittings, they shall be free from sharp angles or projecting edges and of such a size as will enable them to be wired with the conductors used for the final sub-circuits without removing the braiding or the tappings. All the tubes and channels should as far as possible be sufficient size to permit looping back. Flexible wire must not be used for wire fittings except for portable or as mentioned below :—

(*i*) Lamp and accessories :—

(*a*) Lamp holders shall be of B. C. type.

(*b*) Lamp holders for use on brackets shall have not less than $\frac{1}{2}''$ nipple and all those for use with flexible pendants shall be provided with cordgrips. All lamp holders shall carry shade carriers.

(*c*) For pendant fittings lead wire or 23/0076 silk flexible wire be used.

(*d*) The brackets shall be of 9″ projection of strong and durable brass tube. Check nuts shall be used for securing the tube to the base plate which shall also be of heavy pattern brass casting.

(*e*) The lamp shade shall be preferably 9″×5″ opal glass conical shades or any approved.

(*f*) Water tight fitting shall be complete with G. I. brackets with conical reflector. The bracket shall extend 3 ft. from wall and fixed at such a height and angle so as to throw sufficient light on premises. No flexible wires shall be used.

(*g*) All lamps shall be hung at a height of 8 ft. from floor level.

6. Fan and regulators.

(*i*) All ceiling fans shall be wired to a ceiling rose and suspended from clamps, hooks or other fixture already in ceiling and shall be insulated from it. All joints in the suspension

rod shall be screwed and all joints or bolts connected herewith shall be additionally secured by means of split pins.

(*ii*) The canopy at the top of suspension rod shall effectively hide the suspension.

(*iii*) Leading in wire shall be protected from being cut.

(*iv*) Fan point should include the control switch all the wiring required up to the fan and terminals, and fixing of regulators.

(*v*) All fans shall be hung at nine feet above floor level.

(*vi*) Each fan shall have separate switch working in conjunction with regulator.

(*vii*) Points of exhaust fans shall be deemed as equivalent to ceiling fan points and they shall be fixed in position complete with regulators, switch etc.

7. Attachment of fittings and accessories.

(*i*) In other than conduits wiring, all ceiling roses, wall socket, switches, regulators, brackets, and other accessories attached to walls or ceiling shall be mounted on substantial teak wood blocks twice varnished after all fixing holes are made in these. Brass screws shall preferably be used for attaching fittings and accessories to their base blocks

(*ii*) All attachment blocks shall be spaced from wall or ceiling by mean of moisture proof distances not less than $\frac{1}{4}''$ thick.

(*iii*) All accessories viz., regulators, control switches and other fittings for one room be located on one teak wood b oard of suitable size to accommodate the No. of fittings that ma y go on each box.

8. Inter-changeability.

Similar points of fitting and accessories of the same type shall be interchangeable.

9. Earthing the system. All I. C. switches, distribution boards and such other metallic works shall be earthed, by

No. 8 S. W. G. G. I. wire. Earthing plate shall be of G. I. sheet $1' \times 1' \times 1/8''$ placed underground at least 4 ft. depth. The plate to be surrounded by 1 cft. of good quality of charcoal and salt.

10. Method of wiring on T. W. batten.

All cables are to be fixed to wooden battens supported to walls and ceilings. The battens shall be of teak wood or other approved types of wood, free from knots, shaves, sap or other defects and shall have a smooth finish. The batten shall be fixed to the rawl plugs at distance not exceeding three feet by screws.

The cables shall be fixed to the battens by means of tinned link (buckle) clips, spaced at intervals not exceeding nine inches, horizontally and one ft. verticallv. The link clips shall be of adequate size and fitted to the battens by means of brass screws. The heads of all the screws shall be set level with the surface of clips so as not to injure the sheathing of the cables.

11. Plugging. Rawl or other special plugs may be used.

12. Wiring on R. S. Joists, where the wiring is to be carried along the face of the rolled steel joists. a wooden backing, preferably the full width of the joists shall be first laid on the joist and fixed to it as conspicuously as possible. The wiring shall be fixed to this in usual way.

13. Size of battens. The thickness of battens shall be $\frac{1}{2}''$ and width shall be adequate to ensure proper bearing of all cables on the battens, in straight runs of the conductors.

14. Joints. Joints in the straight runs of conductors shall be made by means of brass conductors and closed in joint boxes. The joint boxes shall be such as to prevent insects entering these and to allow of white washing of the walls without water having access to the conductors.

15. Passing Wires through floors.

All wires taken through floors shall be enclosed in a heavy gauge set conduits extending 4 ft 6 inch above the floor and

and finish with ceiling below. The ends of all conduits or pipes shall be neatly bushed with porcelain wood.

16. Wooden battens and any backing used shall be served on all sides before erection with two coats of varnish made up of not less than three pounds of shellac per gallon of spirit. In addition the batten after being put in places (and before wiring is fixed) shall be neatly painted in white or pale yellow colour to match the colour of the walls.

17. Wiring to be of approved quality, *viz.* VIR.; I.C.C.; NICO; or C. M. A.

18. Switches should have porcelain base and should be of Khosla or any other approved good make.

19. Wire should cross the walls through porcelain pipes ½" to 3/4" dia.

20. Iron clads should be M. E. M. make.

21. Shed may be enamel or any good quality.

22. Bulbs shall be of good quality and make.
(*i*) Verandah ... 40 watts.
(*ii*) Rooms ... 25 to 100 as required.
(*iii*) Kitchen ... 60 watts.

23. Weather proof wire may be used in place of lead wire.

24. Switch Boards, with switches of lights and regulators of fans etc. are generally at 5 ft. height from floor level.

25. Pin points for the use are @ 5 ft. distance in switch boards or at 2' with wooden backing from floor level as may be required.

Qualities :—

(*i*) Wire for interior may be VIR 1/18; 3/·029.

(*ii*) Wire for street lights and mains may be Two-wire sub main 3/·029, 3/·036, 7/·029, 7/·036 and 7/·064.

Three-wire sub main 3/·029; 3/·036, ; 7/·029 ; 7/·064 ; 19/·044 ; 19/·052.

Four-wire sub main 3/·029 ; 3/·036 ; 7/·029 ; 7/·036 ; 7·044 7/·064 ; 19/·044, 19/·052 and 19/·064.

(*iiii*) **Overhead service main.**

B. C 2 wire 8, 6, 4. SWG.
B. C 3 wire 8, 6, 4. SWG.
B. C 4 wire 8, 6, 4. SWG.

(*iv*) Weather proof wire. VIR, 3/·029 ; 3/·036 ; 7/·029 ; 7/·306 ; 7/·064 two three or four wires.

(*v*) **Poles** :—A. B. C. or B. C. D. Mannesmen steel tabular $2\frac{1}{4}''$ or 3″ top dia. 28 ft. long.

(*vi*) Stays :—With 7/14 wire plate and rod.

(*vii*) Cables, flexible cords, and wire.

(*a*) WIR, I.C.C. cable 600 maghoms. Grade 250 volts. 3/·029 ; 3/·036 ; 7/·029 ; 7/·036 ; 7/·044 ; 7/·052 ; 7/·064 ; compounded and braided.

(*b*) Weather proof I. C. C. VIR 3/·029 ; 3/·036 ; 7/·029 ; 7/·036 ; 7/·064 ; 250 volts twin.

(*c*) Twin flexible cord glace cotton 250 volts. 600 maghoms I. C. C. Grade 14/·0076 and 23/·0076.

(*viii*) **Conduit fittings** :—

(*a*) Heavy gauge enamelled, 14 gauge, $\frac{3}{4}$ and 1 inch dia.

(*b*) H. G. Conduit bend $\frac{3}{4}''$ or 1″ dia.

(*c*) H. G. Conduit bend inspection $\frac{3}{4}''$ or 1″ dia.

(*d*) Conduit fce ordinary $\frac{3}{4}$ or 1″.

(*e*) Conduit inspection fce $\frac{3}{4}''$ or 1″.

(*f*) Conduit saddle steel $\frac{3}{4}''$ or 1″.

(*g*) Conduit couplas $\frac{3}{4}''$ or 1″.

(*ix*) **Iron Clad Switches.**

(*a*) 15, 30 amp. 250 volts, with double pole iron clad swltches.

(*b*) Senior 15, 30, 60 amps. 500 volts, triple pole iron clad switches.

(*c*) Senior 100 amp. 500 volts, triple pole switches.

(*d*) Senior 500 volts triple pole with neutral, iron clad. switches, 15, 30, 60, 100 amps.

(*x*) **Distribution Boards Iron clad.**

10/15 amp, per way single pole and neutral distribution boards, four, six, eight and ten ways.

(*xi*) **Bus bar Chambers.**

(*a*) Bus bar chambers with two or three way, 100 amps.

(*b*) Bus bar chambers with three ways, 200 amps.

(*c*) Bus bar chambers with 4 ways, 100, 200 and 300 ways.

(*xii*) **Ceiling Fans.**

(*a*) Ceiling fans A. C. single 220/230 volts, 60" and 48" sweep complete with top and bottom ball bearings blades, standard down rod, canopy, shackle and regulator.

(*b*) D. C. Ceiling fans 60" or 48" : 220/230 volts with fittings as in (*a*) above.

(*xiii*) **Table Fans.**

A. C. or D. C. 220/230, 16" sweep complete with blades, flexible oscillating or non-oscillating, regular with or without condensar and extra down rod.

(*xiv*) **Electric Lamp.**

(*a*) Lamp electric vacuum type 230 volts, 15 to 25 watts.

(*b*) Lamp electric gas filled 230 volts ; 200 watts.

(*c*) Lamp electric gas filled, 40, 60, 75, 100 watts.

(*d*) Lamp electric 110 volts 60 and 75 watts.

(*e*) Lamp locks boyonet cap for brass and bakelite lamp holders.

(*xv*) **Fluorescent Fittings.**

(*a*) 5 ft. tube 80 watts.

(*b*) 4 ft. tube 40 watts.

(*c*) 2 ft tube 20 watts.

(*d*) Tube fittings 40 watts × 4′ industrial type with choke, capaciter, starter and switch.

(*e*) 80 watts × 5′ Industrial fittings.

(*f*) Mercury vapour lamp complete with 125 watts, choke, bulb and reflector.

(*xvi*) **Fittings and Accessories.**

(*a*) Single pendent fittings in wrought iron or brass fixed complete with ceiling plate, shade and lamp.

(*b*) Water tight bracket plain 14″ projection fixed complete with cast iron fittings and wall glass.

(*c*) Counter weight fittings single in china fixed complete with flexible wire.

(*d*) Table stand bakelite, or corinthian pillar ordinary complete with shade, switch, carrier and bulb.

(*e*) Table stand decorative (Fluorescent tube) complete with shade, switch, carrier and bulb.

(*f*) Brass bracket 5/8″ × 9″.

(*g*) Double conic street lighting reflector 12″

(*h*) Shade enamelled or plastic 10″ × 3½″.

(*i*) Inspection hand lamp.

(*j*) Tumbler switches with bakelite cover: 5 lamp single pole.

(*k*) Tumbler switches with bakelite cover 10/20 amp single pole.

(*l*) Lamp holder brass rose 5 amp. 2 plate.

(*m*) Lamp holder brass with cord grip shade carrier ring 5/8″ threaded.

(*n*) Wall plug and socket bakelite 2 pin, 5 amps ; 2 pins 10/15 amp-3 pin 5 amp and 3 pin, 10/15 amps.

(*o*) Porcelain cut out 5 amps.

(*xvii*) (*i*) **Miscellaneous.**

(*a*) Teak wood casing and capping, 1″—5/8″ ; 2″ × ¾″%.

(*b*) Teak wood plugs.

(*c*) Porcelain spacing cleats.

(*d*) Corner pieces.

(*e*) Round teak wood blocks 3½″.

(*f*) Teak wood blocks with ply wood backing, sizes 7″ × 4″ ; 6″ × 6″ ; 10″ × 8″ ; 10″ × 12″, 14″ × 12″ , 16″ × 12″ ; 16″ × 14″ and 18″ × 14″.

(*ii*) G. I. Wire Nos. 8 to 10.

(*iii*) Bare copper wire, 7/0 to 1/0 to 10 S. W. G.

(*iv*) Large and small iron clamps for fan with nuts and bolts and fixing.

(*v*) Lightening arrestor ordinary and improved types.

(*vii*) Fancy shades.

(*viii*) Shellac Varnish in gallons.

(*ix*) G. I. earth plate 2′ × 2′ × ¼″ or 1′ × 1′ × 1/8″ complete.

(*xviii*) **Labour.**

For (*i*) Light or fan point in casing and caping complete.

,, (*ii*) Plug points. ,, ,, ,, ,,

,, (*iii*) Plug point in conduit pipe.

,, (*iv*) Fixing iron clad switches 10/15 or 20/200 amps with necessary fixtures.

,, (*v*) Fixing Distribution Board with necessary fixtures.

,, (*vi*) Fixing stays, steel and wooden poles and Cement poles in cement concrete 1 : 3 : 6.

,, (*vii*) Re-wiring of fan, light or plug point in casing or conduits including cast of old stuff.

,, (*viii*) Painting ceiling or table fans with two coats or enamelled points.

CHAPTER I

Water Supply

1. The general sources of supply are—

(*a*) Wells, (*b*) Borings, (*c*) Storage reservoirs, (*d*) Springs, (*e*) Rivers and streams.

2. Daily requirement varies from 15 to 30 gallons, per day, according to quantity of water available.

Gallons per head per day.

Uses	Towns and cities with population				
	Less than 10,000	10,000 to 25,000	25,000 to 50,000	50,000 to 100,000	100,000 to 200,000 and above
1. Domestic Consumption	5	6	6	6	6
2. Bathing and washing	5	6	6	6	6
3. Public Latrine, Urinals, road washing, public gardens and fountains.	2	3	5	5	5
4. Sewer, drain flushing and private W. C. S.	3	3	3	3	3
5. Leakage from water pipes or wastage.	0·5	0·5	1	1	1
6. Filter wash water.	0·5	0·5	1	1	1
7. Stables, cowsheds, Dhobi.	2	3	3	3	3
8. Private Gardens.	2	3	3	5	5
9. Industries 10. Fire Service	Special Arrangements				
Total	20	25	28	30	30

3. Uses for Public Purposes per head per day.

Purpose	Gallons.
1. Public Water taps	... Av. 8 gallons per day per head. (to be calculated from Av. no. of water fetchers) 2 from population of the area depending on P. W. I.).
2. Hotels	... 30.
3. Offices	... 15.
4. Hospitals	... 45.
5. Schools	... 10.
6. Police or Military Barracks.	... 15.

4. **Slow Sand Filters.**

These are masonry structures, bottom and sides perfectly water tight. The whole floor of filter to be covered with two layers of hard bricks, with wide joints so as to form drains all over floor leading to the collecting drains.

Above this fallse bottom 6″ of each :—

6″ of 2″ to 3″ size metal.
6″ of large gravel.
6″ of small gravel.
6″ of coarse sand.

2 ft. of fine sand (residue left between 70 to 100 mesher to the inch).

6″ of very fine sand.

Total 4′—6″.

The top 3 ft. layer of the sand above should be, as nearly as possible of pure silica.

Vertical air pipes, passing through sand should be provided for passage of air to and from the bottom of bed, to avoid the disturbance of the filtering layers.

(5) Design of pipes. (Supply by pressure)

(i) Thickness of pipes (Water mains)

(a) Cast iron pipes $t = \frac{(P+p)d}{6{\cdot}600} + 0{\cdot}25.$

t = thickness of pipe in inches.
d = dia. of pipes in inches.
P = the static pressure due to the head above the pipes in inches.
p = allowance for water hammer.

To ascertain by rapid approximation the weight in tons of a cast iron pipe line.

$w = 25\,mt\,(d+t)$ Add 5% for breakage and where

w = wt. in tons

m = length.

(ii) *Riveted pipes* (Steel)

$$t = \frac{Pd}{2fe}$$

t = thickness in inches.

P = Total pressure in lbs/sq in. includes allowance for water hammer

d = dia of pipe in inches.

f = safe working stress in lbs/sq. in.

e = efficiency of longitudinal joint.

A double riveted lap joints, which is the type most used in riveted pipes, is from 0·65 to 0·75, for triple riveted lap joint, it is supposed to be unity. Value of t found from the formulae is taken to the next larger sixteenth of an inch and then 1/16″ is added to allow corrosion.

(iii) Pressure of water in pipes :—

P = 0·4335 H

P = pressure of water in lbs/sq. inch.

H = Head of water in feet.

(*iv*) Bursting pressure in pipes: Internal diametral pressure tending to burst the pipe produces a stress of :—

$$\frac{P \times d}{2t} \text{ lbs/sq. inch.}$$

Longitudinal stress is :—

$$\frac{Pd}{4 \text{ ft.}} \text{ lbs/sq. inch.}$$

p = Water pressure in lbs/sq. inch.

d = Dia of pipe in inches.

t = Thickness of pipe wall in inches.

For riveted joints, take the efficiency of a joint as 55% for single and 70% for double riveting.

R. C. pipes :—

$$\text{Ac} = \frac{\text{P} \times d \times 12}{2 \times 16000} \text{ sq. inch.}$$

$$\text{Al} = \frac{\text{P} \times d \times 12}{4 \times 16000} \text{ sq. inch.}$$

Ac = Area of circumferential reinforcement per foot, run.

Al = Area of longitudinal reinforcement per foot run.

16000—Steel reinforcement fibre stress.

(*v*) Unbalanced pressure bends.

$\text{U} = 1{\cdot}57 \times P \times d^2 \times \text{s in Q}/2$

u = unbalanced pressure in lbs.

P = water pressure in lbs/sq. inch.

d = dia of pipes in inches.

Q = angle of bend.

Use long radius bends as far as possible.

(*vi*) Spacing of pipe supports :—

(*a*) Stress due to bending is $\frac{fb-3wl^2}{2z}$

L = Distance between supports in ft.

W = Total load (pipe water) in lbs/ft. run.

Z = section moduls of pipes in inches. (Steel area in R. C. Pipes)

(*b*) Longitudinal stress due to water pressure is:—

$$\frac{ft-P\times d}{4\,t}$$

Total stress $= fb+ft.$ whence

$$L = \sqrt{\frac{2\,z}{3w}\ \frac{(f-pd)}{4t}}$$

Take f = 11000 lbs/sq. in. for steel pipes.

8000 lbs/sq. in. for C. I. pipes.

$$\frac{z-\pi}{32}\ \frac{(D^4-d^4)}{D}$$

where d = outer dia of pipe in inches.

(*vii*) Bending moment in pipes :—Taken as thin elastic ring Loaded uniformly on diameter.

$$B.\,M.\frac{WD}{16}$$

D = External dia of pipe.

(*viii*) Time for emptying a water tank.

With a round hole at the bottom (well rounded)

$$T = \frac{A\sqrt{H}}{200\,a}$$

T = Time in minutes.

A = Area of water surface in sq. inch.

H = ht. of water in ft.

a = area of hole in sq. inch.

(*ix*) Rate of discharge from Fire Hydraunts :—

$Q = 24{\cdot}5d^2\sqrt{P}$

Q = Discharge in gallons/minute.

D = Internal dia of hydraunt nozzle in inches.

P = Pressure in lbs/sq. inches.

6. Water Hammer Allowance.

Dia of pipe in inches.	3 to 10	12	16	20	24	30	36	40 to 60
Lbs/sq. inches.	120	110	100	90	85	80	75	70.

7 The appurtenances of pipe line are—

(*a*) Air valves :—Placed at every summit to escape of air when main is filled. They are ball valves lighter than water which close the air vent if air accumulates.

(*b*) Scour valves :—Placed at the bottom of all depressions for emptying Main or letting out sediment.

(*c*) Reflux valves :—On ascending parts of the water main, flap valves which open in direction of flow, but which automatically close if a burst occurs and water flows back. They diminish the damage done by the escape of water burst.

(*d*) Safety or Relief valves :—These are fixed at down stream ends of long lengths of mains, or where water hammer may take place, so as to reduce to normal any excessive pressure that may occur.

(*e*) Sluice valves :—Worked by hand or Hydraulic cylinder for closing main or regulating flow.

(8) Width of trenches :—

3″ to 6″ pipes... 2′—0″

7″ to 9″ pipes... 2′—6″

10″ to 12″ pipes...3′—0″

Minimum cover over pipes should be 2′—6″.

9. Mains and Branches.

Dia of dilivery pipe in inches	Dia of branch pipes in inches.								
	4″	3½″	3″	2″	1½″	1¼″	1″	¾″	½″
4″	1	1	2	6	12	16	30	60	30
3½″	—	1	1	4	8	12	22	45	138
3″	—	—	1	3	6	9	16	30	87
2″	—	—	—	1	2	3	6	12	32
1½″	—	—	—	—	1	2	3	6	16
1¼″	—	—	—	—	—	1	2	4	10
1″	—	—	—	—	—	—	2	2	6
¾″	—	—	—	—	—	—	—	1	3
½″	—	—	—	—	—	—	—	—	1

10. **Stop Cocks** :—In every case a stop cock should be provided within the boundary of premises, between the street main and building and be closed in box.

11. Size of service pipes for house connections.

Class of Building.	Length of service pipe main to House point.			
	100′	50′	25′	10′
Single family house of 2 to 3 storys of not more than 10 rooms	1¼″	1″	1″	3/4
Longer dwelling with about 16 rooms.	1½″	1¼″	1¼″	1″
Four apartment building with about 24 rooms.	2″	1½″	1½″	1¼″
Twenty five apartment building with about 100 rooms.	2″	2″	1½″	1½″

12. G. I. Pipes weight in 100 ft. in Lbs.

Size	B. S. F. 1381/1947			DIN 2440/U
	A	B	B Galv.	
½″	67	83	86	80·5
¾″	100	118	122	103 2
1″	143	166	173	157·4
1¼″	184	237	247	215 8
1½″	234	301	309	248·6
2″	297	383	393	333·4
2½″	415	537	550	480·1
3″	493	635	650	602 6
4″	683	828	850	840·5

13. British Standard Tables of Pipe Flanges (For land use).

Flanges for pipes, valves and fittings.

For working stream pressure up to 50 lbs per sq. inch.

Thickness :— The thickness given in this table includes a raised face of not more than 1/16″ high if such be used. Bolt holes : For 1/2″ or 5/8″ bolts dia of bolt to be 1/16″ longer than dia of bolts 1/8″. Bolt holes to be drilled off centre line.

1	1a	2	3	4	5	6a	6b	6c
Normal size of pipe	Actual outside dia of wrought pipe	Diameter of flanges	Diameter of Bolt circle	No. of Bolts	Dia. of Bolts.	Thickness flanges		
						Cast	Cast iron Steel and Bronze	Iron or steel (staysor Flanged) screwed or riveted or with bas or welded on with fillet.
Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch	Inch
1/2	$2\frac{7}{32}$	$3\frac{3}{4}$	$2\frac{5}{8}$	4	$\frac{1}{2}$	$\frac{1}{2}$	3/8	3/16
3/4	$1\frac{1}{16}$	4	$2\frac{7}{8}$	4	$\frac{1}{2}$	$\frac{1}{2}$	3/8	3/16
1	$1\frac{11}{32}$	$4\frac{1}{2}$	$3\frac{1}{4}$	4	$\frac{1}{2}$	$\frac{1}{2}$	3/8	2/16
1	$1\frac{11}{16}$	$4\frac{3}{4}$	$3\frac{7}{16}$	4	$\frac{1}{2}$	5/8	$\frac{1}{2}$	$\frac{1}{4}$
$1\frac{1}{2}$	$2\frac{10}{32}$	$5\frac{1}{2}$	37/8	4	$\frac{1}{2}$	5/8	$\frac{1}{2}$	$\frac{1}{2}$
2	$2\frac{23}{32}$	6	$4\frac{1}{2}$	4	5/8	$\frac{3}{4}$	9/16	5/16
$2\frac{1}{2}$	3	$6\frac{1}{2}$	5	4	5/8	$\frac{3}{4}$	9/16	5/16
3	$3\frac{1}{2}$	$7\frac{1}{2}$	$5\frac{3}{4}$	4	5/8	$\frac{3}{4}$	9/16	3/8

3½	4	8	6½	4	5/8	3/4	9/16	3/8
4	4½	8½	7	4	5/8	7/8	11/16	3/8
*4½	5	9	7½	8	5/8	7/8	11/16	7/16
5	5½	10	8¼	8	5/8	7/8	11/16	1/2
6	6½	11	9¼	8	5/8	7/8	11 /16	1/2
7	7½	12	10½	8	5/8	1	3/4	1/2
8	8½	13¼	11¼	8	5/8	1	3/4	1/2
9	9½	14¼	12¾	8	5/8	1	3/4	5/8
10	10½	16	14	8	3/4	1	3/4	5/8
*11	11½	17	15	8	3/4	1⅛	7/8	5/8
12	12½	18	16	12	3/4	1⅛	7/8	5/8

*The Association recommends that use of these sizes be avoided.

14. (a) Hazen and William's Formulae.

For flow of water in pipes

$V = 1{\cdot}318C^{0{\cdot}63} \quad R.S^{0{\cdot}54} \quad Q = AV$

V = Mean velocity in ft. per sec.

C = Coefficient of roughness.

S = Hydraulic slope in ft. per foot of length.

R = Hydraulic radius in ft.

(*d*) *Velocities in mains should not exceed* (*with mean of* 10′/*sec.*)—

3ft./sec. for 4″ pipes.

4ft. per sec. for 6″ pipes.

5ft./sec. for 10″ pipes.

6 ft. per second for 16″ pipe.

7 ft./sec. for service pipes (with high velocities in small mains loss of head by friction is excessive).

(Velocities should be high enough to prevent deposits of silt in pipes. 2 to 2½ ft/sec. will be quite sufficient.)

(*c*) *Unwin Formulae to find rough velocities.*

$V = 1{\cdot}45\sqrt{d} + 2 \qquad d = \text{in. ft.} \qquad V = \text{ft./sec.}$

(*d*) *Formulae to find small pipes to take discharge equal to large pipes.*

$$\text{No. required} = \frac{\sqrt{P_1^5}}{\sqrt{P^5}}$$

P_1 is dia. of large pipe ; P is dia. of small pipes.

15. **Discharge capacities of pipes (Discharge varies as $d^{\frac{5}{2}}$ approx.)**

Dia of pipes in inches	Discharge	Dia. of pipes in inches	Discharge
$\frac{1}{2}$	·177	10	316
$\frac{3}{4}$	·485	11	401
1	1·0	12	498
$1\frac{1}{4}$	1·75	13	609
$1\frac{1}{2}$	2·75	14	733
$1\frac{3}{4}$	4·10	15	871
2	5·66	16	1024
$2\frac{1}{4}$	7·60	17	1192
$2\frac{1}{2}$	9·90	18	1375
$2\frac{3}{4}$	12 54	20	1789
3	15 59	22	2270
$3\frac{1}{2}$	22·92	24	2822
4	32	26	3447
$4\frac{1}{2}$	43	28	4149
5	56	30	4930
$5\frac{1}{2}$	71	32	5793
6	88	34	6741
7	130	36	7776
8	181	38	8870
9	243	40	10150

When head lost is required for new smooth pipes, the above values should be reduced by 30%.

18. Tested Pressure.

Class A	...	200 ft. Head
Class B	...	400 ft. Head
Class C	...	600 ft. Head
Class D	...	800 ft. Head

19. Coating of pipes (Dr. Angus Smith's) solution or Coal tar.

(Coal tar)		(Dr. Angus)	
(1) Coal tar	1 part	(2) Coal tar	112 lbs.
Asphalt	3 parts	Paraffin wax	7 lbs.
Linseed oil	5%	Quick lime	10 lbs.
		Resin	1 lbs.

Black naphtha or pitch oil is required to bring the mixture to proper consistency.

20. Minimum weight of wrought iron and steel pipes.

Diameter	⅛″	¼″	½″	1″	1¼″	1½″	2″	3″	4″	5″	6″
Lbs/Ft.	·87	1·2	1·6	2·6	2·7	3·6	7·5	10·6	14·5	18·7	

21. Cast iron pipes and fittings.

(*a*) *Weight of water/yd in lbs. in C.I. Pipes* :—

$$d^2 = \frac{\text{Lbs./yd}}{\text{10 gallons/yd}}$$

d = diameter of pipe.

(*b*) *Flow of water in pipes, diameter, area and displacement* :—

Example. Required the size of a delivery main for a pump delivering 300 gallons per minute against a static head of 400 ft. through a main of 3000 ft. long. The speed of water in mains not to exceed $= \frac{300 \text{ G.P M.}}{250 \text{ ft.}} = 1{\cdot}2$ gls/ft = 6″ pipe (Table C).

Friction head 6" pipe delivering 300 glns per minute
=1·38 ft/100 ft. length (Table *d*)

$$\frac{1{\cdot}38 \times 3000}{100} = 41{\cdot}4 \text{ say } 42 \text{ ft.}$$

∴ Total head pump against 400+42=442 ft.

(*c*) *Dia., Area and Displacement.*

Dia. inches	Area	Displacement in glns/ft. of travel	Dia. inches	Area	Displacement in glns/ft. of travel
1¼	1·767	·0763	24	425·30	19·539
2	3·141	·1356	26	530 90	22 9 5
2½	4 908	·2120	27	572·50	24 732
3	7 068	·3053	28	615 70	26·598
4	12·56	·5426	30	706 80	30 533
5	19 63	·8480	32	804 20	34 741
6	28 27	1·221	33	855 30	36 949
7	38·48	1 662	36	10179 90	43 973
8	50 26	2·171	38	11941 10	48 993
9	63·61	2 747	39	1194 60	51 607
10	78·54	3 393	40	1256 60	54 259
12	113·00	4 881	42	1385·40	59 849
14	150·90	6 649	44	1520·50	65 686
15	176 70	7·633	45	1590·40	68 688
16	201·00	8 683	46	1661 90	71 794
18	254·40	10 990	48	1809 60	78 175
20	314·10	13 569			
21	346·30	14·960			
22	380·10	16 420			

(d) Head in Ft overcome the

Carrying quality per minute

Gallons/minute	I 2″	N 3″	T 4″	E 5″	R 6″	N 7″	A 8″	L 9″	10″
10	·46	·10	...	...	...	...	...	...	...
20	1·61	·24	·09	...	...	...	...	...	...
30	3·45	·57	·14	...	...	...	...	...	...
40	5·4	·86	·23	·09	...	...	...	...	...
50	8·28	1·38	·34	·14	...	...	...	...	...
60	11·5	1·84	·52	·20	·09	...	...	...	...
75	17·8	2·64	·72	·28	·13	...	...	...	...
100	...	4·37	1·75	·46	·20	·10	...	...	...
150	...	9·43	2·42	·86	·39	·21	·10	...	...
200	...	16·1	4·26	1·56	·69	·32	·17	·10	...
300	...	...	9·2	3·16	1·38	·64	·36	·21	·13
400	...	...	15·5	5·52	2·30	1·15	·59	·34	·21
500	...	...	23·0	8·05	3·45	1·61	·86	·52	·31

resistance due to Friction in 100 ft. length.

(Extra for bends & change in section)

D	I	A		O	F		P	I	P E
12″	14″	15″	16″	18″	20″	21″	22″	24″	
...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	
...	...	...	...	..	...	...	...	...	
...	...	...	...	...	...	...	...	...	
..	..	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	
...	...	...	...	...	..	...	...	...	
..	..	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	
·09	...	...	...	...	...	...	...	...	
·18	...	...	...	...	...	...	...	...	

Table 3—Continued

Gallon/ Minute	I 2″	N 3″	T 4″	E 5″	R 6″	N 7″	A 8″	L 9″	10″
1000	...	...	...	..	11·3	4·6	2·48	1·50	·93
1600	...	..	...	...	...	11·3	6·00	3·32	2·00
2000	...	...	...	...	...	18·4	9·66	5·52	3·40
2500	...	...	...	...	...	...	11·5	6·67	4·03
3000	...	...	...	...	...	...	...	10·3	6·10
3500	...	...	...	...	...	...	...	...	8·63
4000	...	...	...	...	...	...	...	...	11·3
5000	...	...	...	...	...	...	...	...	...
5500	...	...	...	...	...	...	...	...	...
6000	...	...	...	...	...	...	...	...	...
7000	...	...	...	...	...	...	...	...	...
8000	...	...	...	...	...	...	...	...	...

D	I	A		O	F		P	I	P E
12″	14″	15″	16″	18″	20″	21″	22″	24″	
·39	·20	·14	·10	...	..	...	...	...	
·90	·44	·32	·23	·14	...	...	...	...	
1·39	·69	·49	·37	·21	·14	·10	...	...	
1·75	·83	·60	·44	·25	·16	·13	·10	...	
2·61	1·21	·87	·67	·39	·24	·20	·16	·10	
3·68	1·75	1·26	·92	·54	·33	·26	·22	·15	
4·83	2·36	1·66	1·23	·71	·45	·36	·28	·20	
9·66	4·60	3·28	2·37	1·36	·83	·67	·55	·	
11·1	5·40	3·91	2·88	1·63	0·97	0·77	0·63	0·43	
...	6·44	4·60	3·40	1·93	1·15	·92	·75	·51	
...	8·62	6·10	4·54	2·56	1·55	1·24	1·00	·67	
...	11·3	8·05	5·75	3·34	2·01	1·61	1·27	0·85	

(e) Table of lengths, thickness

For water supply cast iron)

Internal dia. of pipes.	Length of pipes	Class A pressure 200 Ft. Head.	Weight.			Class B. Test pressure 400 Ft. pressure.	Weight	
Inch	Ft.	Thickness	Cwt.	Q	Lbs.	Thickness	Cwt.	Q
3	9	·38	1	0	17	·38	1	0
4	9	·39	1	2	3	·39	1	2
4	12	·39	1	3	25	·39	1	3
5	9	·41	1	3	26	·41	1	3
5	12	·41	2	2	6	·41	2	2
6	9	·43	2	1	24	·43	2	1
6	12	·43	3	0	21	·43	3	0
7	9	·45	2	3	26	·45	2	3
7	12	·45	3	3	13	·45	3	3
8	9	·47	3	2	11	·47	3	2
8	12	·47	4	2	16	·47	4	2
9	9	·49	4	0	20	·49	4	0
9	12	·49	5	1	17	·49	5	1
10	9	·52	4	7	14	·52	4	3
10	12	·52	6	1	17	·52	6	1
12	9	·55	6	0	5	·57	6	0
12	12	·55	7	3	8	·57	8	0
14	12	·57	9	2	2	·61	10	0
15	12	·59	10	2	3	·63	11	0
16	12	·60	11	1	18	·65	12	0

& weights of pressure Pipes.

SOCKET & SPIGOT

Lbs.	Class C. pressure 600 Ft. Head. Thickness	Weight. Cwt.	Q	Lbs.	Class D. pressure 800 Ft. Head. Thickness	Weight. Cwt.	Q	Lbs.
17	·38	1	0	17	·04	1	0	22
3	·40	1	2	7	·46	1	2	27
25	·40	2	0	2	·46	2	1	1
26	·45	2	0	15	·52	2	1	17
6	·45	2	3	2	·52	3	0	13
24	·49	2	2	27	·57	3	0	12
21	·49	3	2	7	·57	4	0	5
26	·53	3	1	19	·61	3	3	11
13	·53	4	1	22	·61	5	0	2
11	·57	4	0	25	·65	4	2	24
16	·57	5	1	26	·65	6	0	15
20	·60	4	3	23	·69	5	2	8
17	·60	6	1	21	·69	7	1	1
14	·63	5	2	26	·73	6	2	0
7	·63	7	1	23	·73	8	1	26
25	·69	7	3	0	·80	8	3	4
8	·69	10	0	5	·80	11	1	19
11	·75	12	2	25	·86	14	1	8
16	·77	13	3	23	·89	15	3	9
27	·80	15	1	19	·92	17	1	18

Table—Continued

Internal Dia. of pipes.	Length of pipes.	Class A pressure 200 ft. Head	Weight			Class B. Test pressure 400 Ft. pressure.	Weight.	
Inch	Ft.	Thickness	Cwt.	Q	Lbs.	Thickness	Cwt.	Q
18	12	·63	13	1	21	·69	14	2
20	12	·65	15	1	14	·73	17	0
21	12	·67	16	2	12	·75	18	1
22	12	·68	17	3	7	·77	19	3
24	12	·71	20	0	26	·80	22	1
26	12	·74	22	3	2	·83	25	0
27	12	·75	23	3	22	·85	26	2
28	12	·76	25	0	17	·86	28	0
30	12	·79	27	3	24	·89	31	0
32	12	·82	30	3	16	·92	34	0
33	12	·83	32	1	2	·94	36	0
36	12	·87	36	3	7	·98	40	3
38	12	·90	40	0	13	1·01	44	1
39	12	·91	41	2	11	1·02	46	0
40	12	·92	43	0	14	1 03	47	2
42	12	·95	46	2	21	1·06	51	1
44	12	·98	48	1	14	1·08	54	3
45	12	·99	52	0	7	1·09	56	2
46	12	1·00	53	3	2	1·11	58	3
48	12	1 03	57	2	26	1·13	62	2

Lbs	Class C. pressure 600 Ft. Head. Thickness	Weight Cwt.	Q	Lbs.	Class D. pressure 800 Ft. Head. Thickness	Weight Cwt.	Q	Lbs.
5	·85	18	1	12	·98	20	3	4
3	·89	21	1	2	1·03	24	0	19
11	·92	23	0	4	1·06	26	0	9
12	·94	24	3	3	1·08	27	3	24
24	·98	18	0	11	1·13	31	3	19
21	1·02	11	2	17	1·18	35	3	22
27	1·04	33	1	23	1·20	37	3	19
5	1·06	35	3	6	1·22	39	3	22
8	1·09	38	3	6	1·26	44	0	10
23	1·13	42	3	13	1·31	48	3	9
2	1·15	44	3	22	1·33	51	0	11
18	1·20	51	0	3	1·38	57	2	26
21	1·23	55	0	15	1·42	62	2	12
4	1·25	57	1	27	1·44	65	0	18
19	1·26	59	1	18	1·46	67	2	21
24	1·30	64	1	5	1·50	72	3	26
21	1·33	68	3	12	1·53	77	3	24
23	1·35	71	1	23	1·55	80	3	1
27	1·36	73	2	13	1·57	83	2	13
21	1·38	77	3	22	1·60	88	3	14

(*f*) *There are other pipes for Gas & Sewage.*

(*i*) Straight Pipes:—Class A B C D.

Test pressure
Ft. Head 200 400 600 800.

(*ii*) Special pipes. (A & B) (C & D)

Test pressure
Ft. Head 400 800

(*g*) Fittings of A, B, C, & D Class according to the quality of pipes.

(*a*) Socket & Spigot Bends of 90, 45 ??¼, 11¼. degrees.

(*b*) Socket & Spigot 90 degree Duck foot bend.

(*c*) Socket & Spigot Tees & Crosses.

(*d*) Socket & Spigot 45 degree Branches or Ys,

(*e*) Collors

(*f*) Caps

(*g*) Plugs

(*h*) Socket & Spigot central tappers or reducers.

(*i*) Hydaunts Tees & Bends

(*j*) Double socket Horsely syphons.

(*k*) Flanges for pipes, valves & Fittings.

(*ki*) (The working gas pressure up to 30 ft. sq. inch & for water pressure 50 lbs/sq. inch) Flanges are useful for which test pressure does not exceed 300 ft. of water.

(*kii*) Flanges with pressure above 50 ft & up to 130 lbs per sq inch are suitable for pressure not exceeding 600 ft head of water

(*kiii*) Flanges above 130 & up to 175 lb/sq. inch for which test pressure does not exceed 800 ft head of water.

(*kiv*) Flanges are not suitable to boiler feed pipes, other water pipes subject to exceptional shock.

(22) Double Flanged Vertically Cast Iron Pipes & Fittings.

(*a*) The length and the external diameter are the same as those for socket & spigot pipes.

(*b*) The length of double flanged vertically cast iron pipes is generally 9′ & 12′, measured over flanges, except 2″ pipe which are 6′ in length.

(*c*) *Fittings*:—(*i*) Flanged socket, (*ii*) Spigots, Double flanged 90 degree short bends, (*iii*) Double flanged 45 degree short bends, (*iv*) Double flanged 22½ degree short bends, (*v*) Double flanged 90 degree Duck foot Bend, (*vi*) All flanged Tees. (*vii*) All flanged 45 angle Branches or Ys. (*viii*) Double flanged Tapers or reducers. (*ix*) Blank flanges.

(*d*) *Standard Flanged Pipes in use.*

Special Hard wearing C. I. Pipes, with flanged ends for sand stowing.

		Cwt.	Q.	Lbs.
6″ dia 9 ft long	Wt.	6	0	14

with ¼″ thick special flange, 6 holes 7/8″ dia for ¾″ dia bolts. Outer dia of flange 12″ & inner 10¼″ P. C. D.

6″ internal dia.....outside 8·06″.

(e) Special Hard wearing C.I. Pipes for sand stowing.

Bore	Diameter inner	Diameter outer	Dia of flange inner	Dia of flange outer	Thickness of flange	Length	Weight cwt Q lbs	Holes or bolts
		5.98"	9½" P.C.D.	11"	1	9ft	4-3-21	6 holes 11/16" dia 5/8" dia bolts.
5"	4.98"							
6"	5.48"	6.98"	9½"	11"	7/8"	9'	4-0-0	do.
3-3/16"	3-3/16"	5-5/16"	7½"	9"	7/8"	9'	2-3 21	do.
5"	4.86	6.36	8½	10	7/8"	9'	3-2.0	do.

24. (*a*) Spun Iron Pipes. (Socket & Spigot Joints.)

Dia	Length	Thick-ness	Weight Class B. 400 Ft. T.P.	Thick-ness	Weight Class C. 600 Ft. T.P.	Thick-ness	Weight Class D. 800 Ft. T.P.
Inch	Ft.		Cwt. Q. Lbs.		Cwt. Q. Lbs.		Cwt. Q. Lbs.
3″	18	·29	1—2—22	·29	1—2—22	·30	1—2—27
	12		1—0—20		1—0—20		1—0—23
4″	18	·30	2—1— 3	·31	2—1—10	·35	2—2—11
	12		1—2— 8		1—2—13		1—3— 4
5″	18	·31	2—3—16	·34	3—0—15	.39	4—2— 4
	12		2—0— 0		2—0— 8		2—1—20
6″	18	·33	3—2—18	·37	4—0— 6	·43	4—2—14
	12		2—2— 3		2—3— 4		3—0—19
7″	18	·34	4—1—15	·40	5—0— 7	·46	5—2—26
	12		3—0— 3		3—1—26		3—3—20
8″	18	·36	5—1— 3	·43	6—0—21	·49	6—3—22
	12		3—2—16		4—1— 0		4—3— 1
9″	18	·37	6—0—11	·45	7—1— 1	·52	8—1— 1
	12		4—0—24		4—3—27		5—2—18
10	18	·39	7—0—10	·47	8—1—15	·55	9—2—17
	12		4—3—17		5—3— 1		6—2—12

Dia	Length	Thickness	Weight Class B 400 Ft. T.P.	Thick-ness	Weight Class C 400 ft. T.P.	Thick-ness	Weight Class D 400 ft. T.P.
inch	Ft.		Cwt. Q. lbs		Cwt. Q. lbs		Cwt. Q. lbs
12	18	·43	9—0—10	·52	11—1— 2	·60	12—3— 7
	12		6—1— 2		7—3— 0		8—3— 3
14	18	·46	11—1—12	·56	14—0—14	·65	16—0—17
	12		7—3—10		9—2—26		11—0— 9
15	18	·47	12—1—17	·58	15—2—14	·67	17—3— 5
	12		8—2— 8		10—3— 2		12—0—24
16	18	·49	13—3— 0	·60	17—0—19	·69	19—1—26
	12		9—1—27		11—3— 8		13—1—12
18	18	·52	16—1—14	·64	20—2— 4	·74	23—1—19
	12		11—1— 6		14—0— 6		16—0— 7
20	18	·55	19—0—18	·67	23— 3— 1	·77	26—3—23
	12		13—0—24		16—1—11		18—1—26
21	18	·56	20—1—24	·69	25—2—15	·80	29—1— 8
	12		14—0—13		17—2—14		20—0—10
22	18	·58	22—1— 9	·70	27—1—18	·81	31—1—3
	12		15—1—22		18—3—19		21—1—27
24	18	·60	25—0—16	·74	31—1—23	·85	35—2—18
	12		17—1—15		21—2—21		24—1—27

(*b*) **Spun iron pipes screwed gland joints.** Used where particularly a quick and simple mechanical joint is called for its design incorporates lead-tipped rubber ring, which is compressed and held in position by an internal gland screwed into position of socket.

Specials are also available in the variety.

These are used for quick work, where traffic of special nature is included. These can be quickly filled in with minimum delay traffic.

24. Cast iron accessories.

(*i*) Reservoir valve tower.

(*ii*) Syphon draw off pipes.

(*iii*) Draw off sluices and screens.

(*iv*) Drainer of settling tanks.

(*v*) Well sluice.

(*vi*) Single and double faced sluice.

(*vii*) Open channel sluice valve.

(*viii*) Dock sluices.

(*ix*) Culvert sluice.

(*x*) Filtering apparatus of water mains.

(*xi*) Rose pieces (stainers).

(*xii*) Reservior ventilators.

(*xiii*) Fire hydraunts.

(*a*) Stand pipes for hooked outlet hydraunts, with screwed bayonet joint or instantaneous, meter stand pipes type.

Kinds of piller and sunk hydraunts :

(*b*) Residual pressure for fire hydraunts with pumping engines=10—20 lb/sq. inch.

For direct flow from hydraunts

=50—75 lbs/sq. inch.

(*xv*) *Cocks, Taps & Fittings* :—

BIP Cocks (Taps).
Stop cock.
Self closing tap.
Ball taps.
Ground stop cocks.
Globe stop valves.
Check valves.
Relief valves.
Ferrule taps.

(*xvi*) *Controlling fittings.*

(*a*) Ferrule connections.
(*b*) Check valves.
(*c*) Relief valves.
(*d*) Full way wheel valves.
(*e*) Half way wheel valves.

25. Galvanized Iron Pipes & Fittings.

(a) *Particulars of Screwing.*

Dia.	Outer Dia.	Number of threads per inch	Approx. length of useful threads			
			Class A		Class B and C	
Inch	Inch		Inch	turn	Inch	turn
⅛	27/32	14	13/32	5¾	17/32	7¼
¼	1-1/16	14	15/32	6½	9/16	8
1	1-11/32	11	17/32	5¾	21/32	7¼
1¼	1-11/16	11	19/32	6½	¾	8½
1½	1-29/32	11	19/32	6½	¾	8½
2	2⅜	11	23/32	8	29/32	10
2½	3	11	27/32	9¼	1-1/16	11½
3	3½	11	15/16	10¼	1-3/16	13
3½	4	11	1	11	1¼	13½
4	4½	11	1⅛	12½	1-13/32	15½
5	5½	11	—	—	1-19/32	17¼
6	6½	11	—	—	1-19/32	17¼

(*b*) GOOD DIE should have following characteristics. :—

(*i*) Lip angle for screwing hard steel 15° to 20°.

(*ii*) Lip angle for screwing soft steel 22° to 25°.

(*iii*) Lip angle for general purposes average 22½°.

(*iv*) Throat angle 12½° to 15°.

(*v*) Clip space should provide an even curve for chip to follow as it comes of the tube.

(*vi*) *Clearance* A screwing dia with correct clearance will show 1/16″ to 3/32″ of poloshed thread, where it has been in contact with the thread of the product.

(*vii*) Ample flow of lubricant is at all times essential. Soluble oil or fuels are preferable to straight cutting oils.

(*c*) *G. I. Fitting and Specials.*

(*i*) Pieces, long screws & double long screws.
(*ii*) Barrel Nipples.
(*iii*) Equal Elbows.
(*vi*) Equal tees.
(*v*) Equal cross.
(*vi*) Elbows reducing,
(*vii*) Tee reducing.

(*viii*) Tees reducing (On the run and Branch or on the run only).

(*ix*) Tees (Increasing in the Branch)
(*x*) Crosses reducing.
(*xi*) Side out let.
(*xii*) Side out let elbow.
(*xiii*) Side out let cross.
(*xiv*) Elbows, Round, Male and Female Equal.
(*xv*) Socket equal.
(*xvi*) Socket reducing.
(*xvii*) Caps.
(*xviii*) Elbow equal 135 degrees.
(*xix*) Y pieces equal.
(*xx*) Plugs.
(*xxi*) Hexagonal Backnuts.
(*xxii*) Running Nipples & Close tapper nipples.
(*xxiii*) Male elbows.

(*xxiv*) Male Tee.
(*xxv*) Male Cross.
(*xxvi*) Y Pieces Male.
(*xxvii*) Male angle Tee.
(*xxviii*) Male Twin Elbow.
(*xxix*) Male sweep Tee.
(*xxx*) Bushings.
(*xxxi*) Nipples, Hexagonal equal.
(*xxxii*) Union Bends.
(*xxxiii*) Pipe Unions.
(*xxxiv*) Socket unions.
(*xxxv*) Flange for low pressure services.
(*xxxvi*) Gunmetal & Brass valves & Cocks. (*a*) Steam valve. (*b*) Gate valve. (*c*) Steam gland cock. (*d*) Steam plug cock. (*e*) Bibcock Round crutch. (*f*) Hose Union bib cock.

26. Asbestos cement pressure pipes—According B.S. 486.

Asbestos cement pressure pipes are manufactured in lengths of 2 meters for 1½" Class C and D; 10 ft (3·05m) length for 2" (50 mm) classes C and D, 3 in. (75 mm) Classes B, C, D, and 4 inch (100 mm) classes B, C, and D are all large diameters.

2 metres = 6 ft. 6¾"
= 2·187 yds. (804 pipes/mile)
10 ft. = 3·333 yds. (526 pipes/mile)
4 metres = 13 ft. 1½"
= 4 375 yds. (402 pipes/mile)

(*a*) Class A :—Test pressure 200 ft. (61 m) head of water 86·7 lbs/sq inches.

(*b*) Class B :—Test pressure 400 ft. (122 m) head of water 174 lbs/sq. inches.

(*c*) Class C :—Test pressure 600 ft. (183 m) head of water 260 lbs/sq. inches.

(*d*) Class D :—Test pressure 800 ft. (244 m) head of water, 348 lbs/sq. inch.

N. B. 1½" class A or B, 2" classes A or B or 3" class A. Class A are not generally used for water supply purpose.

(e) Size, Thickness & Weight. (Asbestos Cement Pressure pipes).

Dia. Inches	Class A		Class B		Class C		Class D	
	Shell Thickness Inches	Wt. Lbs. per pipe	Shell Thickness Inch	Wt. Lbs. per pipe	Shell Thickness Inch	Wt. Lbs. per pipe	Shell Thickness Inch	Wt. Lbs. per pipe
1½	—	—	—	—	0·38	15	0·38	15
2	0·39	—	0·39	—	0·39	30	0·45	33
3	0·40	—	0·40	43	0·50	53	0·55	57
4	0·42	51	0·47	88	0·61	110	0·66	118
5	0·46	103	0·55	127	0·71	157	0·78	172
6	0·49	137	0·61	167	0·78	208	0·90	235
7	0·53	172	0·66	210	0·87	269	1·03	312
8	0·57	210	0·72	261	0·96	338	—	401
9	0·60	236	0·79	305	1·05	394	—	460
10	0·64	279	0·84	359	1·16	481	—	—
12	0·68	348	1·00	517	1·17	597	—	—
14	0·79	468	1·15	688	—	—	—	—
15	0·84	532	1·23	785	—	—	—	—
18	1·00	755	1·47	—	—	—	—	—

Note : The seweights are subject to variation of plus or minus 5%.

(*f*) *Types.* There are two types :

(*i*) Screw joints.

(*ii*) Cast iron detachable joints.

Pipes have plain ends and are joined by means of flexible joints.

(*g*) *Method.* Rubber is the medium of jointing employed in all joints. In case of cast iron detachable joints, the metal components must be protected from corrosion, by a liberal application of bitumen or tar.

In case of aggressive soils it is necessary that detachable joints be protected by using a metal mould and filling solid with bitumen.

Moulds are of aluminium.

(*h*) *Joints* :

(*i*) *Asbestos cement screw joints*—		(*ii*) *Detachable joints*—	
(*a*) Central collor of Asbestos cement	1 No.	(*a*) Joints Flanges	2 Nos.
(*b*) Circular gland of Asbestos cement	2 Nos.	(*b*) Rubber rings	2 Nos.
(*c*) Rubber rings	2 Nos.	(*c*) Joint collor	1 No.
		(*d*) Wrought iron bolts	3 Nos

(*i*) *Service.* Service may be taken as below :

(*a*) Where lead service pipes are to be used, the pipes can be tapped direct as in the case of C.I. Mains, with existing tackle. The ferrule is screwed in and service connection taken. For bad traffic conditions, a malleable iron saddle piece service condition is advised. This consists malleable iron strap bolted round the pipe with parkerized bolts. The upper half has a flat base and both the base and pipe are drilled and tapped to take the ferrule.

The saddle piece service conditions are undrilled. When saddle has been bolted in position a hole is drilled and tapped through both, giving a continuous thread. A flat rubber washer is first fixed between the underside base and outer surface of the pipe.

(*j*) *Laying* :—Bottom of trenches to be properly levelled and pieces of stores and hard material removed and layer of at least 6″ sand laid before laying the pipe.

Sufficient clearance of making joints should be allowed by additional excavation at those joints.

(*k*) *Specials* :—

(*i*) Asbestos cement bends of 90, 45 and 22½ degrees.

(*ii*) Cast iron specials shall have plain ends.

(*iii*) Cast iron detachable joints must be used for connecting cast iron specials to the pipes.

(*a*) Cast iron bends of 90, 45, 22½ and 11¼ degrees.

(*b*) Hydrant Tees.

(*c*) Flange Adapter.

(*d*) Cross.

(*e*) Reducers.

(*f*) Equal Tees.

(*g*) End Caps.

(*h*) Unequal Tees.

(*i*) Angle Branch.

(*l*) *Covering* :—Minimum cover at the points of crossings and traffic position should be atleast 2′—6″ and ordinarily minimum 1¼ ft.

27. Water meters.

The meters are from ½″ to 6″ size.

Size of inlet in inches	Daily capacity in Gallons	Delivery not to exceed glns per hour	Oral indications
½″	4200	10	1/10th gallon up to 1 million gallons.
¾″	6400	20	
1″	10000	30	
1¼″	13000	45	
1½″	22000	75	1 gallon to 10 million gallons.
2″	20600	120	
3″	19200	180	
4″	26800	240	
5″	49800	300	10 gallons to 100 million gallons.
6″	57500	360	

Note. Meters of 2″ to 6″ sizes have dirt boxes, with arrangement of removing or lifting dirt with strainers.

28. (*a*) Pumps.

Where the pumped water is let out directly in mains without intermediate service reservoir, pumping capacity should be 3 times the average demand per hour.

$$\text{Brake H.P. required} = \frac{G \times \text{Head in ft.}}{3300 \times \text{pump efficiency}}.$$

G = Water to be supplied in gallons per minute.

Head = Static Head (Positive for rising mains and negative for gravity mains) plus friction head.

For losses due to friction and slip of valves add one-third of the static head.

1 H.P. = 33000 lbs. lifted one ft. in one minute.

= 530 cft. of water lifted one ft. in one minute.

The pressure of atmosphere will support the lift of 34 ft. and this is a limit of theoretical height where water can be lifted if there is perfect vacuum in suction pipe. It is not possible practically to pump through that height, as the pump can never create a perfect vacuum, because of friction losses. Therefore pump is not used for a greater total suction height than 24 ft., without boosting or a deep well pump. Suction pipes should never be less in diameter than delivery pipe or pipes. Where no stainer is required the pipe should have bell mouth entry. Both suction and delivery pipes to be free from bends and elbows as far as possible. A check value is placed on discharge suction side to prevent backward surges of pressure which may damage the pump. A gate valve be preferably be provided to ensure repair to check (or non-return) valve. A gate valve is also provided on suction side.

(*b*) Theoretical H.P. to pump through 1000 ft. of pipe.

Discharge	Dia of pipes in inches (suction pipe)							
In gallons per min.	1¼	1½	2	2½	3	4	5	6
	Horse power required							
40	5·4	2·5	0·9	—	—	—	—	—
60	—	8·0	2·8	0·9	—	—	—	—
80	—	18·3	6·4	2·1	0·9	—	—	—
125	—	—	20·3	7·1	2·9	0·6	—	—
160	—	—	—	15·5	6·3	1·5	—	—
250	—	—	—	—	20·5	5·0	1·7	—
330	—	—	—	—	—	11·3	3·8	1·6
425	—	—	—	—	—	21·6	7·3	2·9
500	—	—	—	—	—	—	12·2	5·1

(*c*) *Pumping efficiency.*

Electric 9 to 95%
Diesel oil 70 to 80%
Steam 60 to 70%

(*d*) *Types of pumps.*

(*i*) Deep well ordinary multistage centrifugal; air lift submercible.

(*ii*) Deep well turnbine 4" min. size, Air lift, Rotary, continuous, flow ; reciprocating ; Ejector jet.

(*iii*) Low lift—Centrifugal—low head, centrifugal propellar centrifugal nixed low.

(*iv*) High pressure. Centrifugal ; multistage ; rotary ; reciprocating. (For high lifts head 100 to 150 ft.)

(*v*) Booster. Centrifugal ; single or multistage ; reciprocating.

(*vi*) Fire—Centrifugal (with positive primming device), Rotary reciprocating.

(*vii*) Small centrifugal, reciprocating, rotary perpheral (Centrigugal) ; Hydaulic-Ramm.

(*viii*) Stand by : Centrifugal (with positive priming device reciprocating.

(*ix*) Centrifugal pumps can be divided into two types.

1. The volute type.
2. Guide vane type.

9. Wells.

(*a*) *Size of well.*

$$A = \frac{D \times 10{,}000}{h}$$

A = Area of well in sq. ft.

$$= \frac{\pi d^2}{4}$$

D = Discharge in cusecs.

h = Depression Head in ft.

(*b*) *Recuperation test :—*

Darcy's law: $K/A = 2{\cdot}303/T \log H/h$ value of K/A is constant as long as velocity of inflow does not exceed critical velocity below which surrounding soil is not disturbed. The maximum yield will be obtained when it is worked continuously without exceeding the critical velocity.

The actual velocity worked out from the formulae should be less than critical velocity. K/A is the yield in cubic feet per hour per sq. ft. of area of well, (bore through which water percolates) under a head of one foot. (Value of K is 1 for wells in coarse sand and the yield will be 2·5 cft. per sq. ft. per hour for head of depression from 5 to 7 ft.) K/A is 0·5 for wells in fine sand and 0·25 in clay. A is area of well in sq. ft. H is Head of depression in feet. *h* is the rise in feet during the observation time (*i. e.* H and *h* are depths of water below normal water level in time interval *t*.) *t* is the time in hours of observation. A factor of safety of two to four is usually taken but it may have to be as high as 10.

(*c*) *Tube well.*

Methods: (*i*) Rotary boring. (*ii*) Core drilling. (*iii*) Water jet boring. (*iv*) Percussion rope boring (Rope system). (*v*) Telescoping boring.

Hitches: (*i*) Sand blowing. (*ii*) Tammed pipes due to sockets.

Materials: (*i*) Blind pipe. (*ii*) Housing pipe. (*iii*) Frozen pipe. (*iv*) Bail plug. (*v*) Shoes. (*vi*) Boring tube joints. (*vii*) sldger of stand pump. (*viii*) Strainers.

(d) Open wells.

The Thickness of steening of wells (Brick work in Cement mortar 1 : 3)

Depth of well from ground level in feet.	Thickness or diameter of well in feet						Notes.
	5′	10′	15′	20′	30′	40′	
10	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	(*i*) Open well can be provided with a cylinder submerged in water.
20	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{7}{8}$	$2\frac{1}{4}$	
30	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{5}{8}$	(*ii*) Rubble masonary steening for small depths and thickness to be 3″ to 6″ more than brick work.
40	$1\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{5}{8}$	$2\frac{3}{8}$	
60	$1\frac{7}{8}$	$1\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{5}{8}$	3′	$3\frac{3}{4}$	
80	$2\frac{1}{4}$	$2\frac{5}{8}$	3	$3\frac{3}{4}$	4	$4\frac{1}{2}$	(*iii*) Discharge of open well may be increased by sinking a tube well in its bed. The bottom of the well is sealed with cement concrete.
100	$2\frac{1}{4}$	3′	$3\frac{3}{8}$	$3\frac{1}{2}$	$4\frac{1}{2}$	5	

Open well should be protected by curb and platform all round.

CHAPTER I

Drainage : (*i*) Subsoil drainage.

(*ii*) Drainage of land to carry to the sewer, cesspool, septic tank or sewerage purification plant.

Where sullage and storm water have to be dealt with, with no night soil, surface drains of V-shaped section with segmental inverts are quite satisfactory. These drains may be with pre-cast R. C. C. slabs, which can be removed for clearing silt or any chockage in the drains. Stone ware pipes, R. C. C. spun hume pipes and plain concrete pipes are also used for this purpose, with cleaning chambers or Manholes at suitable length and directions or the diameter of pipes changes for cleaning purposes. Where there is a kink or change of dia or change of directions, a drop is necessary in the manhole or cleaning chamber. (*i.e.* the inlet is at higher point more than gradient, than outlet). Where there is danger of collection of silt, a silt chamber is provided at the bottom of the manhole. This is cleaned, when full with silt.

Rain water is determined by :—

$D = R \times A \times F.$

D = Discharge in cusecs (Total run off)

R = Intensity of max. rainfall in inches per hour.

A = Area to be drained in acres.

F = Factor of imperviousness or Co-efficient.

Open Drains.

Open drains should not have steeper slope than 1 in 200, otherwise scouring will occur. Where steep slope cannot be avoided, drop walls and wier cushion be provided at suitable intervals.

Sometimes a well hole is necessary, which is shaft in which a large amount of sewerage drops a long distance. The force of fall may be broken by staggered horizontal plates, a flight of steps or by means of a well or sump at the bottom from which the sewerage overflows to the low level water. Under culverts drains should be steeper gradients, say double. Open drains should be ½ to 1 slope.

(1) *Impervious factor or Run off Co-efficients:*

Kuichlings Values.

1.	Water tight roof surfaces	·70—·95
2.	Asphalt pavings in good order.	·85—·90
3.	Stone, brick, (with cement joints)	·75—·85
4.	Stone brick work (without joints)	·50—·60
5.	Macadamised roadways and wells	·25—·60
6.	Unpaved roads, open land or gardens	·15—·25

(2) **Velocity and Gradients**, for storm water drains.

Dia	Min Gradient	Permissible velocity	Dia	Min Gradient	Permissible velocity.
3″	1 in 40	No limit	12	1 in 270	8′/sec.
4″	1 in 60	No limit	15	1 in 410	6′/sec.
5″	1 in 80	10′/sec.	18	1 in 600	6′/sec.
6″	1 in 100	9′/sec	21	1 in 800	6′/sec.
7″	1 in 125	9′/sec.	24	1 in 960	6′/sec.
9″	1 in 185	9′/sec.	30	1 in 1300	6′/sec.

(3) *Materials* :—For underground drains up to 18" dia, glazed stone ware pipes of plain concrete pipes may be used ; for large size Hume pipes or Spun R. C. C. pipes may be used. Wherever syphoning is necessary cast iron pipes should be used.

(4) *Size*:—The sewers or the drains shall be designed to run from half to two-third full, when discharging at maximum rate the latter may be taken as being approximately twice average dry weather flow or one half of average daily discharge in 6 hours, so that the capacity of sewer, when running full will be from 3 to 4 times average dry weather flow, thus allowing not only for fluctuation in hourly rate of latter, but also for a small quantity of rain water.

(5) *For Sewers:*—Below 6" dia pipe 200 gallons.

6" to 9" 500 ,,

9" to 15" 700 ,,

15" and above 1000 ,,

(6) Slopes of Sewers :—

(*a*) Slopes of sewers should be as steep as possible. The slopes will be adjusted according to the calculated velocity.

(*b*) Minimum Gradients of sewer.—

(*i*) Internal 1 in 125

(*ii*) Out falls 1 in 500 to 800

(*iii*) Intercepting in upper length 1 in 300

(*iv*) Intercepting towards ends 1 in 500

(*c*) Velocity Formulae : $V = C\sqrt{RS}$

$V = C\,1\ R2/3\sqrt{S}$

R= Hydraulic mean radius

$$= \frac{\text{Cross-sectional area.}}{\text{Wetted perimeter.}}$$

$= d/4$ for circular drains.

S= Gradient. C may be taken 125 for glazed surface, 100 for cemented and 85 for brick drains.

Cl=1·486/h. "h" has the same value as in Kutter's formulae. For Glazed 140, for cemented surfaces 124 and brick drains 114.

(*d*) Self cleansing velocities, for sewers.

	Diameter of pipes in inches	Gradient.
Where falls are restricted and where drains are well designed and well laid the slopes to be 1 in 50 for 4" dia pipes and 1 in 75 for 6" dia pipes.	4	1 in
	6	1 in 60
	9	1 in 90
	12	1 in 120
	18	1 in 150
	24	1 in 200
	30	1 in 250
	36	1 in 300

Note :—4½ ft/sec. is limit for sewers. Side sewers and drains must enter main tangentially.

(*e*) Storm drain gullies or inlets : Depend on longitudinal fall and cross fall are between 150 to 300 ft. and each gully must drain at least 2500 sq ft. Inlets may have catch pits (Silt Chambers) about 2' deep below invert of out let. Cover of grating to have openings, parallel to flow.

(*f*) *Sewers*: (*i*) Tributary sewers, who enter in the manhole should deliver sewage in the direction of main flow in through the manhole by an arrangement of inverts.

(*ii*) Sewers at junctions, kinks and curves should have extra fall to compensate for friction and interruption of flow.

(*iii*) Where branch sewers enter M. H. on the Main sewer line at a higher level than the main, a drop pipe should be given to avoid scouring and sudden thrust.

(*iv*) House drains should not pass direct to sewers from the house, but all house drains should end at an outside wall and should come in inlet chamber with trap (Gulley trap) on sewer side.

House drains, sink pipes and soil pipes should be well ventilated.

(*v*) Manholes or Lamp holes, sizes and spacings :—

(*i*) 2 ft. dia—300 ft.
(*ii*) 3 ft. dia—450 ft.
(*iii*) 4 ft. dia—600 ft.
(*iv*) 5 ft. dia and above 900 to 1200 ft.

Manholes should be in straight line of sewer. Provide Manholes or Lamp holes at change of gradient Alignment and size of pipes.

(7) Width For Trenches.

(*i*) Minimum 21″ wide.
(*ii*) Dia+15″.
(*iii*) At joints width of colour or socket plus 18″.

(8) Channelling in Manholes :—(Slope Min: 1 in 30).

Dia.	Depth at Centre	Depth at Sides.	Dia	Depth at Centre	Depth at Side.
4″	6″	10′	15″	17″	21″
			18″	21″	24″
6″	8″	12″	21″	24″	30″
9″	11″	13″	24″	30″	36″
			30″	36″	39″
12″	14″	18″	36′	39″	42″

Depth of Manholes, Chambers, Lamp holes :—

(*i*) Depth is counted from top of floor of cement concrete to below of concrete for cover. The thickness of top slab is not counted in depth. Manholes should not have more than 2 branches, channels on either side (Rectangular) (*i*) $3'-4\frac{1}{2}'' \times 2'-3''$ (min) up to 7 ft. deep.

Above 7 ft. in height lower portion can be $4' \times 4'$ up to $4'-6''$ height and upper a shaft $2'-7\frac{1}{2}'' \times 1'-10\frac{1}{2}''$ size or $5' \times 3'$ and $2' \times 3'$ sq. shafts. (These are internal dimensions).

(*ii*) Excavation of Manhole should be sufficient alround to allow correct plastering for outside and to enable the masons to sit and work freely. (In case outside plaster is provided) Outside plaster is required where Manholes are within 10 ft. of buildings or suitable structures like Bridges etc.

(*iii*) Foot rests (Manhole Treads or rungs) are necessary, where depth is more than 2 ft. Foot rests of M. S. rods of 7/8" bars or Cast iron foot rests should be fixed after coal tarring or properly painting with approved paint at 1' depth and 1 ft. apart. Vertically and Staggered.

(*iv*) Circulars 2' dia Min (inside) increasing towards the bottom according to the depth and size of sewer. A circular Manhole is stronger than rectangular or square, one.

(*v*) Min. brickwalls 9" thick with 1 : 5 cement up to 10 ft. depth with cement concrete of 1 : 5 : 10 at bottom 9" thick projecting 6" beyond walls. Shaft and Manhole opening can be controlled over for reducing size. Inside to be cement plaster $\frac{1}{2}''$ of 1 : 3 mixture up to corbelling, and $\frac{1}{2}''$ to $\frac{3}{4}''$ from outside (if necessary).

(*vi*) *Ventilation* :—Vent shafts on sewer line may be between 4" to 6" dia at a distance of 400 ft.

For cleaning, M. H. to be left open for atleast one hour before entering in. At least 3 Manholes to be opened at a time for ventilation, one on either side of Manhole to be inspected.

(*vii*) Road boxes for cocks small and medium sluice values.

Ordinary and light traffic		Heavy traffic	
Size	Height	Size	Height
4″ dia.	1½″ to 3″	7¼″×4″	2″ to 4″
5¾″ dia.	1½″ to 3″	8″×5″	2″ to 4″
7″ dia.	1½″ to 3″	10¼″×6″	2″ to 6″
7″×4″	1½″ to 3″	10¼″×13½″	6″ to 7″
8″×5″	1½″ to 3″	11¼″×14¼″	6″ to 7″
10″×6″	1½″ to 3″	12¾″×16½″	6″ to 7″
8½″×8½″	1½″ to 3″	21″×14″	6″ to 7″
12″×12″	2″ to 4″	27″×16″	
14½″×14½″	2″ to 5½″	18″ to 72″ ×34″	
10¼″×13½″	2″ to 4″		
11½″×14½″	2″ to 4¾″		
12″×16¼″	3″ to 6″		

(*viii*) Manhole Grating Ventilation Covers.

Outside size of frame	Size of opening	Outside size of frame	Size of opening
	Ordinary	**Traffic**	
3′—8″ × 2′—8″	3′—0″ × 2′—0″	2′—3″ × 2′—3″	1′—9″
3′—10″ × 2′—4″	3′—0″ × 1′—6″	2′—0″ × 2′—0″	1′—7″
3′—4″ × 2′—10″	2′—6″ × 2′—0″	2′—2″ dia	1′—10″ dia.
Light Traffic		**Heavy Traffic**	
3′—6″ × 2′—6″	3′—0″ × 2′—0″	3′—4 dia.	1′—7″ dia.
3′—8″ × 2′—2″	3′—0″ × 1′—6″	3′—0″	1′—9″ dia.
3′—0″ × 2′—6″	2′—6″ × 2′—0″		
3′—2″ × 2′—2″	2′—6″ × 1′—6″		
2′—7″ × 2′—7″	2′—0″ × 2′—0″		
2′—0″ × 2′—0″	1′—6″ × 1′—6″		
1′—8″ × 1′—8″	1′—0″ × 1′—0″		

(*i*) *Heavy covers* :—
Weight not less than $4\frac{1}{2}$ cwt. Height 9″ frame and cover.

(*ii*) *Ordinary traffic* :—
Weight not less than 4 cwt. Height 7″

(*iii*) *Light traffic* :—
3 to 1 cwt. Height 3″ to 6″.

(*iv*) *Light and non-traffic areas.*
Not below 150 lbs. Height 2″ to 4″.

Stone Ware Pipes

(9) Salt Glazed pipes and sockets.

Internal dia. in inches	Thickness of barrel and sockets in inches	Min. internal depth of socket in inches	Min. excess shoulder in inches	Min. length of grooving on spigot in inches
3″	7/16″	2″	5/16″	3″
4″	1/2″	2″	3/8″	3″
5″	9/16″	2¼″	7/16″	3⅜″
6″	5/8″	2¼″	7/16″	3⅜″
7″	11/16″	2¼″	7/16″	3⅜″
8″	11/16″	2½″	1/2″	3¾″
9″	3/4″	2½″	1/2″	3¾″
10″	13/16″	2¾″	5/8″	4⅛″
12″	1″	2¾″	5/8″	4⅛″
15″	1¼″	3″	5/8″	4½″
18″	1½″	3″	5/8″	4½″
21″	1⅝″	3¼″	3/4″	4⅞″
24″	1¾″	3½″	3/4″	5¼″

13. Laying.

(*a*) Horizontal drains and waste pipes shall be carried with a minimum fall of $\frac{1}{2}''$ per foot for pipes of 4″ dia. and smaller. Pipes larger than 4″ shall have atleast $\frac{1}{4}''$ per foot. Drain lines shall be laid true to grade and alignment. Changes in direction shall be made as far as possible by providing Manholes or inspection Chambers, with curved fitting, bends having long sweep or Y branches and $\frac{1}{8}$th bend.

(*b*) *House Drains.* House drains to be connected with the sewers by gully trap or Nihani trap, at a distance of atleast 8 ft. from the outside of the walls of the buildings. Sufficient no. of cleanouts shall be provided at traps, bends etc., to allow ready access to cleaning. The pipes are to be carefully bedded along their whole length on the bottom of trench, joint holes being excavated to receive the sockets.

(*c*) *Depth.* If the depth of the excavation is more than 3 ft. and there is no danger of traffic passing over it, there is no necessity to provide concrete, underneath or for haunches in case of R.C.C. pipes. But in case of stone ware pipes or plain concrete pipes is necessary to have atleast 6″ concrete below and up to haunches or incasing. Where the depth is less than 3ft., there R.C.C. Hume or spun pipes should be provided with 6″ concrete underneath and up to haunches. The stoneware pipes or plain concrete pipes should not only have bed concrete of 6″ to 9″ but should be fully covered atleast at joints.

(*d*) *Joints.* Joints to be properly cleaned. Atleast 150 ft. of straight line be laid at a time. The spigot of the pipe to be carefully wrapped with a ring of spun yarn, dipped in cement grout or tarred gaskin, sufficiently thick to fit tightly the socket of the adjoining pipe and allow of proper alignment, the yarn or tarred gaskin being carefully driven home, with a cawking tool. All the stoneware pipes, plain concrete pipes, R.C.C. hume or spun pipes are to be jointed with mortar 1 : 1 (one part of well screened and clean fine sand mixed with minimum quantity of water) to form plastic mortar, will completely fill up the space in the socket, and shall be neatly bevelled off upon the outside of pipes allronnd the circumference and finished at an angle of 45 degrees outside the sockets or the collors of the pipes. When the joint has been completed, it shall be

protected by moist sand, wet gunny bags or by other suitable method. In joining the pipes care is to be taken that none of the jointing materials shall be left inside the pipes.

Pipes to be cleaned with brushes before laying and sufficient shield shall be placed within the mouth of the pipes to prevent stones and rubbish getting in while the operation of laying is in progress. A tightly fitting bags of shavings or straw having a rope attached is to be kept working inside and along the line of pipes while being laid to remove all the obstructions from interior. In all junctions of pipes, sewers, stoppers must be inserted and cemented in so as to ensure the joints being water tight until the branch connected is completed.

(14) **Instructions** :— (*i*) Trench to be levelled and place of sockets trowelled.

(*ii*) The bottom of trench is rammed up.

(*iii*) The earth must be packed and rammed with wooden rammers under the haunches of the pipes.

(*iv*) Earth should be filled in layers of not exceeding 6″ in depth and each layer to be rammed carefully.

(*v*) No heavy rammers to be used.

(*a*) Where the pipe line is passing near the building or near any important structures and depth is not more than 2′-6″ but where there is no danger of traffic 6″ thick concrete 1 : 4 : 8 should be laid under the portions of joints. 3″ more on either side of the socket and filled up to haunches to prevent any leakage.

(*b*) Where the pipes are passing through made up soil region, uneven surface of rocky nature or very loose soil shall be laid on cement concrete of 1 : 4 : 8 or 1 : 5 : 10, not less than 6″ thick and minimum width equal to external diameter of the pipes plus 12″ and shall be haunched with same concrete up to not less than half the external diameter of the pipes. (And when passing near or through or under very important building) the joints to be encased in cement concrete of 1 : 4 : 8 and 6″ thick in case of R.C.C. hume or spun pipe, but in case of

stoneware pipes or plain concrete (*i.e.* on reinforcement) pipes the whole pipe line to be encased completely.

(*d*) When passing through any stream or water tank, the pipes to be laid on concrete bed 1 ft. thick of (1 : 2 : 4) 15″ wider than the dia of the pipe, encased with 6″ concrete throughout the length and straped properly with proper bolts and nuts, the bolts being fitted in bottom concrete.

(*e*) The pipe line shall have all inlets properly trapped with an efficient trap having a water seal of 2″.

(*f*) Pipe shall if disconnected by an intercepting trap from the sewer, have such trap provided with a raking arm, a water seal of atleast 2″ and be fixed as near sewer as possible.

(*g*) Pipe shall be water tight and capable of resisting a pressure, equal to 2½ lbs per sq inch.

(14-A) Test of pipe line and Joints. (Absorptiontest B. S. S. No. 35).

(*i*) Shell Thickness up to 1″ 7% increase in wt.

(*ii*) Shell Thickness up to 1¼″ 8% increase in wt.

(*iii*) Shell Thickness up to 1½″ 9% increase in wt.

(*a*) *Hydraulic test* : Pipes should be able to withstand a bursting pressure of 25 lbs/sq. inch for atleast 5 seconds without showing signs of injury or leakage. After the joints of certain section are laid *i e.* between Manhole or Chamber to Chamber or Manhole and sufficiently cured (atleast for seven days) before the trenches are allowed to be filled in, the pipe can be tested for water tightness by filling the pipes with water completely in the length to be tested, by closing the ends of the section by a water tight plug. Observe the water for an hour. The level must remain the same. Generally a length of 100 to 300 ft. is taken (preferably between two Manholes). Lesser length for bigger diameter. A plug is inserted at the lower end of each length or in case of bigger dia where plug is not available, 9″ masonary is constructed and plastered from outside to make it leak proof, and a right angled bend at the top (preferably glass bend) and funnel fixed through a rubber

tube or testing rubber plug is used (A drain plug is cylindrical bag of rubber and canvas to which a tube and a tap valve is fixsd at one end. Air is pumped in the plug which is inflated and blocks the passage of water. After air bubbles have escaped after first filling, water is again added to completely fill the pipes. Permissible drops in a 6″ funnel per 100 ft. length of pipe line is :—

4″ to 6″—¼″	It is satisfactory if water level
9″—½″	does not fall more than ½″ in length
12″ to 15″—1″	of 300 ft. within one hour.
18″—2″	If the water level is more than
21″—3″	permissible joints to be properly ins-
24″—4″	pected and leakage attended to pro-
30″ and above 6 ft.	perly.

(c) Smoke Test : It consists in filling the whole sanitary system with smoke so that it may find its way through any leaky joints or defective trap, and thus demonstrate the exact position of faults In applying this test the steps of waste pipe and soil pipe must be properly closed and smoke applied through the air inlet of the intercepting traps of the waste pipe and soil pipe must be properly closed and smoke applied through the air inlet of the intercepting trap, at the junction of the house drain and the sewer. For this there is a special smoke testing machine. (The machine consists of a double action bellows or motor by which the smoke is forced, a cylindrical or receptacle in which smoke is generated by burning oily cotton waste, and a pipe connecting these are carried in to the drain. Smoke rockets are some times used for the same purpose but the results are not so good. This test is quite practical

and useful and may be applied either in vertical soil pipes, drain ventilating pipes or inspection chambers.

(d) **Chemical Test** : This test is applied by pouring two or three buckets of very hot water with a fluid dram of some volatile oil down the highest available spot. If on inspection of each joint a peculiar smell is perceived the leakage will be discovered. (This is not a satisfactory test)

(e) **Pneumatic Test** : It consists in driving air under pressure into drain and soil pipe by a pump, to which is attached a pressure gauge after all the openings have been securely plugged. The presence of any leakage is evidenced by lowering of the pressure in gauge and the point of leakage by hissing sound.

(f) **Crushing Test on pipes** : Stone ware only. (4" or 6" dia).

Each pipe is prepared for test by casting two fillets of plaster of paris and sand diametrically opposite to each other on the surface of the pipe barrel extending from the back of the socket to the spigot end. Each fillet was made 1" wide and thick enough to compensate for inequalities of the pipe barrel. Two steel bearing plates each one inch wide and long enough to cover the whole length of pipe barrel and sufficiently rigid to receive and transmit the load without deflection, are then placed on the edge on the above fillets and the pipe was then subjected to a crushing, load increasing at the rate of about two thousand lbs through these steel bearings.

Total crushing load in Lbs	4" pipe	6" pipes
Lineal foot (of the barrel)	4,838	4,368
Crushing strength in lbs/ft length	2419	2184

The breaking test of S. W. pipes should not be less than 1700 lbs/ R ft. (Same applies with plain concrete pipes.)

15. Septic tank.

(*a*) This was first devised by Mr. Cameron of Exeter under the name of septic tank system. But the first systematic study of biological process of the treatment of sewage in the tropics was undertaken by Mr. Fowler and Mr. Clemesha in 1906 and an arrangement known as the Septic Tank Latrine, which consists of a latrine built acually on the roof of the septic tank, has been introduced. These latrine arrangements are useful for mills, jails and schools etc. A septic tank is a combination of settling, digestion, sludge storage tank in a single structure. It is a watertight structure.

(*b*) An efficient septic tank should be a rectangular single chamber basin. Its size should be such that it has a retention period of approximately 24 hours to the daily flow of sewage into it, considering sludge storage. Attention should be given to the length, bread h and depth of septic tank. The dimensions to be such that there are no dead spots or short circuits. For this the septic tank should be designed with length not less than twice the width and not more than thrice the width, and a minimum liquid depth of 4 ft measured at the outlet end. Baffles are nowadays undesirable as these do not permit a slow uniform horizontal flow from end to end. Baffles introduced increase velocities aud turbulence and curtail sludge storage space.

Submerged inlets and outlets with S.W.G. sanitary Tees are preferable to any other arrangements. There should be hydraulic fall of 3" from the inlet to outlet end. Wooden hanging scum boards may be provided at inlets and outlets in place of sanitary Tees. Bottom must have slope of 1 in 10 towards the inlet. No vent is necessary. There should be a minimum air space of 22" between the underside of the covering slab and the top of the liquid in the tank. The top end of the outlet Tee should remain open to serve as vent and the top end of the inlet Tee is to be plugged with wooden plug. Manholes should be provided for periodical removal of sludge and scum, by sludge pumps or manually.

30 gallons per capita/day for dwellings.

15 gallons per capita in public places, *viz.*, Cinemas etc.

10 gallons per capita in schools, offices etc.

Min. capacity of septic tank should be 500 gallons.

There is no objection to soap water etc. being used for household purposes, but as far as possible disinfectants or antiseptics such as soap water and phenyl should not be used for cleaning lavatories or Septic Tank. These are injurious to the bacterial purification process.

Plumbing fixtures should not be blocked by rags etc. Septic roof slab should be at an elevation of atleast 6″ rom ground level.

(C) Construction. A septic tank is built of (*i*) Cement concrete, (*ii*) Brick in cement masonary (1 : 3), (*iii*) he thickness as per the structnres and R.C.C. slab with two manholes of 2 ft × 2 ft. size. (*iv*) Cement plaster 1 : 3 is necessary inside to ensure watertightness.

(D) Disposal of effluent : (Filter or Contact Beds)

Liquid is free from solids, but contains many bacteria dangerous to health and much organic matter in solution. This organic matter putrefies and causes offensive odours if run out on surface. (*i*) Safe method is by sub-surface absorption. This is accomplished in suitable soils by disposal of effluent about 12″ under ground. It flows through open jointed or perforated disposal pipes.

(*ii*) No. of oblique trenches 18″ width and not more than 3 f. deep are excavated. The pipes, stoneware, perforated or R.C.C. with holes at 12″ C.C. 44 from bottom on the both sides are laid over 1 ft. of boulders roughly packed, 6″ layer of 1½″ metal or spoil stones of 1½″ to 2½″ size and 6″ layer of coarse sand properly levelled and covered with 6″ of coal ash and then covered with ordinary earth level with the existing ground. The distance between the disposal trenches

should not be less than 6 ft and in uniform grade of 1 in 200, with suitable manhole at 300 ft. lengths and at the end for cleaning, in case of chockage.

(*iii*) Importa t points : (*a*) Build a manhole in the septic tank.

(*b*) Bottom must have a slope of 1 in 10.

(*c*) Do not forget to build a collection chamber at the inlet and distribution chamber at the out from where disposal pipes shoot.

(*d*) The ground alround the septic tank should be sloped on either sides, and not towards the septic tank.

(*e*) Alround the septic tank [masonary at least 1½ ft. width must be filled with boulders and moorum or with other suitable materials, specially in black cotton soil, to, prevent thrust of outside earth pressure, etc.

(*iv*) **Required Capacity for Septic Tanks.**

No. of Persons	Capacity of Tank	Dimensions.				Capacity in cft.
		Width	Length	Liquid depth	Total depth	
4 and 6	500	3′	6′—10″	4′	5′	100
8	500	3′—3″	7′—0″	4′	5′	1 4
10	700	3′—6″	8′—0″	4′	5′	140
12	840	3′—6″	8′—6″	4′—6″	5′—6″	164
14	980	4′—0″	9′—0″	4′—6″	5′—6″	193
16	1120	4′—0″	10′—0″	4′—6″	5′—6″	200

(v) Capacity required for schools, offices and public places :—

No. of persons		Capacity in gallons	Dimensions				Capacity in cft
Public places	Schools and office		Width	Length	Liquid depth	Total depth	
40	60	600	3′—6″	8′—3″	4′—0″	5′—0″	140
80	120	1200	4′—6″	13′—8″	4′—6″	5′—6″	266
120	180	1800	5′—0″	11′—6″	5′—0″	6′—6″	374
160	240	2400	6′—0″	12′—9″	5′—0″	6′—6″	500
200	300	3000	7′—0″	14′—0″	5′—0″	6′—6″	637
240	360	3600	7′—0″	16′—0″	5′—0″	6′—6″	751
280	420	4200	7′—6″	16′—6″	5′—6″	7′—0″	866
320	480	4800	8′—0″	17′—6″	5′—6″	7′—0″	980

Note :— 2000 users 60′ × 12′ (width) × 7′ 6″ (Total depth). Septic tank should have atleast 6″ min bed concrete of 1 : 3 and 6″ Root Slab thickness of R.C.C.

(*vi*) **In some Septic tanks** :— The sewage effluent is allowed to remain in or pass so slowly through the settling tanks that putrefaction takes place and helps to break up the solid content of the effluent and reduce the amonnt of sludge. In this process the settling tanks, for daily flow of 1,000,000 gallons of effluent :—

	S ay in Tanks. Hours	Number o' Tanks	Spare Tank.	Capacity of Tank in Gallon s.
Continuous Flow Settlement	15	⁵	2	833,333
Quiescent Settlement	2	1)	2	1,041,600
Septic tank	24	6	6	1,200,000

(*vii*) *Activate l Sludge System.*

A recent system which has met with success is known as activated sludge, and consists of breaking up the solid contents of sewage by introducing air und r pressure. The settling or disintegration tanks are of special design, and the air is introduced under pressure, of 5 to 10 lbs/sq. inch at the bot om keeping the sewage in constant state of agitation. After leaving the settling or disintegration tanks, the effluent passes through a mixing chamber previously aerated sludge from the channel is intimately mixed with the incoming effluent. Air diffusers are fixed all along the channels and the three necessary constituents of purification (sewage and activated sludge)

are in intimate contact. From the channel the liquid passes to a final settling tank and then direct to a suitable outfall, or effluent disposal beds.

16. Perforating Filters.

These are generally six feet in depth and circular and filled with porous material like brickbats, stones, metal cinders (coal ash) etc. varying from $\frac{1}{4}$" to 3" scientifically graded over which the effluent is sprinkled through fixed sprinklers, dripping trays, tipping troughs or by revolving sprinkling arms, which revolve horizontally over a circular bed to ensure uniform distribution. This is suitable for only bath and kitchen waters. It is necessary to provide sedimentation tank for separating humus from purified effluent.

17. Conservancy system.

(*a*) *Latrine Privy.* (*i*) It should be well designed so that all excreta and wash water will automatically find their way in some receptacle.

(*ii*) Materials to be non-absorbent to prevent pollution of the soil through soakage.

(*iii*) Satisfactory arrangements for reception of night soil and liquid excreta should be made.

(*iv*) Ventilation should be through and efficient even when doors are closed.

(*b*) *Construction.* (*i*) Superstructure—Height to be not less than 8 ft. from the seat and at least with 1 ft. plinth.

(*ii*) Floor and seat should be stopped towards the opening or drain leading to receptacle.

(*iii*) Foot rests must be in right position or else faeces will not fall in receptacle below, sides of opening to be stopped as to prevent fouling.

(*iv*) Collecting chamber should have cement concrete floor atleast 6" above ground level.

(*v*) Pail or receptacle should be direct below the opening.

(*vi*) Shall be atleast 20 ft. away from the buildings.

(*vii*) Shall be 100 ft. away from a well or water stream.

(*c*) *Types.* (*i*) Basket system.

(*ii*) Well or pit latrine, (The well underneath the seat should be atleast six feet deep). This is called squatting plate latrine.

(*iii*) Bore hole latrine.
(*iv*) Commode.
(*v*) Chemical closet.

18. Cess pool.

It may be circular or rectangular. This is a small tank, where effluent of latrine or privy, bath and kitchen collects and is removed either mechanically or manually in hand carts (motor) and taken outside habitated area and thrown.

A cesspool shall not be less than 100 ft away from building, a well, a spring, a stream or a tank. It shall be covered on top, and ventilated,

19. Slop Sink.

Max. size 63″×21″, height 2′—10″ and draining board 3′—10″, above floor level. Kitchen sinks are 18″×18″ or 24″×24″ shall have a wastes of lead, copper, cast iron or wrought iron nihani traps. The internal diameter of a watei pipe from the single sink is $1\frac{1}{2}$″ dia. to 2″, And shall hav. a water seal not less than $1\frac{1}{4}$″ to $1\frac{1}{2}$″. The sinks or nihan traps are used in kitchen bath, washing places, urinals etc This shall be lead to Manhole or Chamber, of sewer and gutter or hopper head of rain water.

20. Baths. (Porcelain type)

Usual dimensions : Length 5′—6″ to 6′—0″. Overall width 28″ to 30″. Depth inside at waste 17″ to 18″. Height overall with feet 23″, 24″. Supply pipe min. $\frac{1}{2}$″ dia. and waste pipe $2\frac{1}{2}$″ to 3″ provided with nihani trap. It is connected with anti-siphonage pipe.

Note. It is better to connect bath room, kitchen, washing place, wash basin, urinals, nihani traps with 3″ dia. pipe to a chamber provided with a gully trap before taking to sewer manhole. W. C. to be independently connected to sewer manhole.

21. Water closets.

In buildings water closets are constructed according to the direction of prevailing winds.

(*i*) Commode type (European type). Height 16″, length 20″ to 25″.

(*ii*) Seat type (Indian). Length at top 23″ to 27″, width at top 16″ to 21″ (including trap). T p is flush with floor and two steps above.

(*a*) One of the walls must be an external wall, not more than 5′ above the level of W. C. Floor, or on an open space not less than 100 sq. ft. in area and not more than 5 ft. above the level of W. C. Floor. The minimum width of this space should be 3′, if open on one side and 7 ft. if closed on every side.

(*b*) Shall if the floor of W.C. is more than 5′ below ground level, have one of its sides an external wall abutting on an open area having a superficial area of atleast 40 sq. ft. with minimum width of 5′. The open area to be covered by a grating and must abut on a street and be not less than 12 ft. below such street.

(*c*) Entrance not to be from any room used for habitation, unless it is only meant for bed room or dressing room.

(*d*) Shall be properly sealed and enclosed with solid walls.

(*e*) Shall, where entered directly from external air, be provided with an impervious floor at least 3″ above the level of the street or area from which it is entered.

(*f*) Shall have a window with net, not less than 2 sq. ft. in area of which at least one sq. ft. shall open.

(*g*) Shall have an air brick or air shaft for ventilation.

(*h*) Shall have suitable flushing cistern discharging or flushing capacity of not less than 2 gallons of water and be capable of re-filling in less than 2 minutes at a height of 6½′.

(*i*) Shall have flush pipe between the closet pan and the flushing cistern not less than 1½″ dia.

(*j*) Shall have tap of not less than ½" dia for ablution purpose.

21. Construction.

An intercepting trap of minimum water seal of 2" is provided and jointed to the soil pipe outside.

The closet outlets should be unglazed on outside for atleast 2" to 3" for making a cement joint with soil pipe. The trap has an opening at the upper portion for joining with anti-siphonage pipe. An inspection cover is provided in the soil pipe opposite the trap. Pan is provided with after flush chamber to ensure proper seal. The back of the pan is as near vertical as possible to prevent fouling.

Commode type. Should have closets which have the traps above the floor and to those in which connnection with the soil pipe is taken direct through the external wall.

(*Suitable types.* Syphon jet syphmication.)

Seat type. Closets with pool of water are not to be used for their liability to splash. Suitable is with art pool of water. Minimum dimensions to be 4'×3', with minimum height of 8' from the floor and a dado of 3 ft. above floor must be plastered or tiled. Cistern to be atleast 3/16" thick C. I. or of wrought iron.

22. Urinals.

Height of porcelain urinal shall be 2'—6" above floor level, for males only. Average spacing is 2'—6" per stall, depth 1'—2" and height of screen above floor level is 3'—6". Flushing cistern 1 gallon (Automatic).

23. Earth closets.

(*i*) Shall have atleast two external sides and be entered direct from external air.

(*ii*) Shall be built of solid walls like W. C.

(*iii*) Shall be paved with hard materials.

(*iv*) Shall have space beneath the seat of sufficient size to permit the removal of receptacle containing walls of impervious materials.

(*v*) Shall have hinged seat and urine trough.

(*vi*) Shall have sufficient natural lighting ventilation.

(*vii*) Shall have a satisfactory arrangement for application of sufficient quantity of dry earth.

24. Wash Basin.

Height from floor 33" width well 18" to 20". Wash basin is provided an anti-siphonage pipe (or non-siphoning traps are used). Underneath is a nihani trap taken to a chamber of gully trap by a soil pipe of not less than 3" dia. with an inspection cover near nihani trap.

25. Chemical Toilet.

This is a seat attached to a metal cylindrical tank having a capacity of 100 to 125 gallons per seat. The tank may be of copper bearing s eel which is resistant to the action of chemical use. A solution of 25 gallons of caustic soda to each 100 or 150 gallons of water sterilizes and liquefies the excreta in the tank and requires replacement at intervals of several months.

Contents of the tank when required to be emptied, is liquid, sterile and free from odour or smell.

...Septic Tank. (Vertical and Horizontal)

Reinforced cement concrete on centrifugal system.

Limit—Internal depth, 5′—10″.

Max capacity gallons	Scum board feet	Length flow feet	All waste		WC/waste		C/only		Dimensions			
			No. of persons	Max. gln per head	No. of persons	Max. gln per head	No. of persons	Max. gln per head	Internal dia.	Thickness of walls floor and seat	Outer dia at bottom	Distance from C of tank to C of outlet
161	4·22	5 88	4	40	8	20	13	12	3′	2″	3′—4″	8¾″
223	6·44	7·06	6	37	13	17	19	12	3′—6″	2⅜″	3′—10¾″	11¾″
295	9·04	8·25	9	33	18	16	27	11	4′—0″	2¾″	4′—5½″	14¾″
375	12·03	9·42	12	31	24	16	36	10	4′—6″	3″	5′—0″	17¾″
466	13·52	10 60	16	30	31	15	47	10	5′—0″	3″	5′—6″	20¾″
567	19·36	11·79	19	29	39	15	58	1	5′—6″	3¼″	6′—½″	23¾″
677	23·61	12 96	24	25	47	14	71	10	6′—0″	3½″	6′—7″	26¾″

Note. Asbestos cement septic tanks are also produced but for 5 consumers only. With ...bic feet capacity of 6·83 and withhold 42·89 gallons.

27. Asbestos Cement.

Rain water and soil goods :

(*i*) No painting is necessary.

(*ii*) No rusting or rotting.

(*iii*) They are light and easy to fix.

(*iv*) They can be cut wit' saw.

(*a*) *Ornamental and half round gutters and specials*—

(*i*) Pipes of 6′ length plus sockets.

(*a*) O.G. 5″ and 8″ dia.

(*b*) H.R.=6″, 8″ and 12″ dia.

(*ii*) *Specials*. Drop-ends, stop ends (for spigot and sockets) union clips, nozzles, internal angles, external angles, angle with outlets, boundary wall gutters and valley gutters.

(*b*) (*i*) Single socketed pipes. Lengths 10, 6, 3 and 2 ft. plus socket. Diameters, (Internal) 2, 2½, 3, 3½, 4 and 6 inches.

(*ii*) *Specials*. Swan neck, double inverted junction. Drain about, Rain water head, cone cap cowl, shoe slotted vent cowl, loose socket, double equal junction with access door and bend plain.

Note. The pipes are fixed with walls with heavy galvanized clips.

(*c*) *Jointing*. A.C pipes—(As done in S.W. pipes).

Gutters. Plastic roofing bituminous compound should be used for jointing all classes of A.C. gutters in preference to red lead. Putty or any other compound which dries and so looses ductility in these conditions. When used for sanitary purposes *i.e.* from a trap to gully trap etc., pipe should be laid on 4″ C.C. (1 : : 4 : 8) and encased properly.

(d) Sectional Areas of Gutters.

Size	Type	Area sq. inch	Size	Type	Area sq. inch
12″	H.R.	56·55	20″×6″×10″	Boundary wall	90
9″	H.R.	31·81	18″×6″×12″		90
6″	H.R	14·14	12″×6″×9″		63
8″	O.G.	37 66	11″×5″×7″		45
5″	O.G.	12·00	36″×8″×9″	Valley	180
			24″×6″×9″		99
			18″×5″×6″		60
			16″×5″×10″		65

28. Sizes of pipe for house.

(i) *Soil pipes 4″ Main waste pipes 2″ to 3″.*

Branch soil and waste pipe		Vent pipes (Main)	
For W.C.	4″	For W.Cs.	3″
For slop sink	3″	For other fixtures	2″
Urinals	2″	*Branch vent pipes.—*	
For bath tubs	2″	For W.C. and slop sink	2″
Kitchen sinks	2″	Other fixture	1½″
Laundry tubs	2″	*Sizes of traps.—*	
Wash basins	1½″	For W.Cs.	3½ to 4″
Flushing pipes.—		Slop sinks	3″
Height of cistern above pan	2′, 4′, 8′, 12′	Kitchen sink	2″
		Wash tubs	2″
Diameter of flush pipe	2½″, 2″, 1½″ 1¼″	Urinals	2″
Diameter of flush valve	2″, 1½″, 1½″, 1¼″	Wash basin and pantry sink	12″
For urinals dia. of flush valve	⅛″ smaller		

29. Light rain water pipes. (*i*)

Size	2″	2½″	3″	3½″	4″	These pipes have ears for fixing against walls
Internal dia.	1⅞″	2⅜″	2⅞″	3⅜″	3⅞″	
Wt/6 ft. length in lbs.	17	19	23	28	30	

(*ii*) *Soil pipes.*

Dia.	Thickness of metal (not less than)		Weight/6 ft. length (including socket)	
	A class	B class	A class	B class
2″	—	3/16″	—	28 lbs.
3″	5/16″	3/16″	110 lbs.	44 lbs.
4″	3/8″	3/16″	160 lbs.	54 lbs.
5″	3/8″	¼″	190 lbs.	69 lbs.
6″	3/8″	¼″	230 lbs.	84 lbs.

Note. A are used for under ground and B above ground.

(*iii*) *Weight of lead and Gasket for cast iron soil pipes.*

Dia. of pipes	2″	3″	4″	6″	8″	10″	12″	14″	16″	18″	20″
Load lbs.	2·5	3 5	4 5	6·4	9	13	15	18	22	26	33
Gasket lbs	·125	·170	·170	·200	·200	·250	·250	·375	·500	·500	·625

30. Wrought iron and steel pipes for sanitary purposes.

Dia. of pipe ...	1¼″	2″	3″	4″	5″	6″
Wt. lbs/ft. ...	2·68	3·61	7·54	10·66	14·50	18·76

31. Weight of brass pipes for sanitary purposes.

Dia.	1½″	2″	3″	4″
Wt. lb/ft.	2·84	3·82	7·92	11·29

Note. Lead pipes are used for short branches of soil, waste or vent connections.

32. Standard for Public Sanitary conveniences.

Public Latrines ...1 seat for 50 (water closets).

Cinemas ...1 W.C. for every 400 seats and 1 urinal for every 200 seats.

Schools ...1 W.C. for 25 boys or 15 girls.
1 urinal for 15 boys or 13 girls.
Above 100, provide 1 seat for every 50 boys or 25 girls plus one seat extra, in each case.

Factories ...1 seat for every 20 up to 100 and above 100, 1 seat for every 50. Urinals at 4% (or provide according to the local factories etc.)

Note. *Annual Maintenance* :—1% is provided on the initial expenses.

33. Disposal.

(*i*) *Incinerators for town refuse.* These are conveniences for final disposal of town or city refuse. The larger types are composed of one or more cells, each designed to dispose 8 to 10 tons per 24 hours daily and utilising the heat developed for boiler and industrial purposes. These are termed as destructors also. Types—

(*i*) House fall.
(*ii*) Beeman and Deas.
(*iii*) Meldrum.
(*iv*) Heenan and Froude.
(*v*) Sterling.
(*vi*) Baker. House fall type is used at Calcutta and Colombo.

Daily refuse varies between 1/2 to one ton per thousand population or about 7 cwt/head per annum In wet weather refuse is 25% heavier.

(*ii*) *Disposal on land.*

(*iii*) *Artificial purification.* Separating bulky parts to such an extent that it is rendered non-putrescible and is delivered on land or into river or stream.

GENERAL INFORMATION AND ESTIMATING

CHAPTER I

1. **Decay and preservation of Timber.** Wet rot may occur while tree is standing. White ants are injurious to timber. Teak, Sal and Deodar withstand attack of white ants. Fungi will not attack if moisture is below 20%. Good air circulation and seasoning are best preservatives. Application of chemical and creosote oils is also preservative. Ascu handiproof, coal tar are good preservatives.

2. **Knowtting, brimming and spotting.**

Knowtting :—For covering knots, 5 oz. of pure shellac dissolved in a pint of methylated spirit ; when thoroughly dissolved ½ oz. of red lead stirred in.

(*ii*) Two parts of whiting (absolutely dead stone lime), one part of white lead mixed together in linseed oil and kneaded (3 oz. linseed oil to 1 lb. of whiting will also do). For high class works, spotting can be made of 1/3rd of white lead and 2/3rd of ordinary putty.

(*iii*) **Beaumohtage or spotting.** Outvax is a useful preparation for concealing all defects in wood work. One cup of eommon shellac, tea spoon of powder resin, a piece of bees wax (1" dia) and tea spoon of powdered lemon crome or other colouring matter. Heat until the whole is melted, mix well and apply when hot. This will not take stains, so it should be coloured to suit the finished work. It sets quite hard.

(*iv*) **Putty.** One seer finelly powdered whiting, one chhatak white lead (dry), 6 chhataks raw linseed oil ; lit argo to be added as drier. For glazing in metal sashes, 5% red lead to be added. (Whiting is dead stone lime.) Well mixed by hand and kneaded into stiff paste, and used after twelve hours.

3. Paint Removers. (*i Caustic soda* :— 2 lbs. of caustic soda to one gallon of hot water. Use with caution and do not leave on wood and do not touch with hand. Apply and wash with clean water (Wood work).

(*ii*) *Naphtha* :—Wet the paint with naphtha, repeat, when softened, rub and clean (Wood work).

(*iii*) *Country soda* .—Dissolve one lb. country soda in hot water and mix 4 lbs of stone lime and make paste, apply, leave three hours and clean (Wood work .

(*iv*) *Slaked lime and soda* :—Mixed in equ l parts will remove iron work paint. One maund for 800 sq. ft. (Iron work).

(*v*) *Solution of potash* :—Potash two par's, soft soap one part, quick lime one part, in boiling water Apply hot. Leave for 12 to 24 hours. Wash and clean with hot water (Iron work).

4. Polish.

(*i*) *French Polish* :—½ lb of best refined seedlac (shellac), pint of methylated spirit or naphtha, strained through a thick cloth twice. Wood to be polished should be first painted with filler, and sand-papered properly.

(*ii*) *Filler* :— 5 lbs of whiting mixed in 1/3 gallon of methylated spirit or whiting with water, linseed oil and beeswax, 3 : 1 (boiled), plaster of paris either in water or linseed oil.

(*iii*) Raw linseed oil is also good for polishing.

(*iv*) *Wax polishing* :—Two parts of bees wax, 2 parts of boiled linseed oil, over a slow fire. When dissolved add one part of turpentine. Smear wood work with mixture and after 24 hours, rub with a soft flannel to a fine polish.

(*v*) Whiting mixed with size and water is used for whitening ceiling and walls. Whiting is made by reducing pure white chalk to a fine powder.

(*vi*) *Varnishing* :—Wood work for varnish should be sized with a coat of thin clear glue to which a little brown earth and ochre should be added if wood is oily. This should be applied hot and rubbed smooth. A second coat of thin clean glue with necessary quality of staining colour consisting of equal parts of burnt umber and burnt sena should be applied. When dry,

rubbed smooth with fine sand paper. Two coats of boiled linseed oil can be given instead of glue size. Varnish to be laid in thin coats over this when dried. English copal varnish is the best. Varnish should dry in two days. One pint varnish will cover about 150 sq. ft.

5. Oiling. One pound of bees wax, 3 lbs of double boiled linseed oil are heated over a slow fire till wax is melted. After cool add 1 lb of turpentine. This will cover 800 sq ft. Or country sweet oil with equal parts of vinegar and turpentine, This is bit darker.

6. Painting Iron Work.

(*a*) *Iron under water* :—(*i*) Refined coal tar, dissolved in a vehicle.

(*ii*) Asphalt dissolved in asphaltum in suitable vehicles *viz.*, Naphtha or benzene is also good for iron under water. This is especially effective for cast iron works for water pipes.

(*iii*) Coal tar 84 lbs., mineral pitch 10 lbs. slaked white lime or cement 9 lbs. and kerosene oil 9 lbs. Total 112 lbs=one Cwt. Heat the pitch and coal tar separately. Mix when hot, add slaked lime gradually. Then put off and add kerosene oil. Do not heat beyond 350 to 450 F°. Quantity 1 cwt for 2500 sq ft.

(*b*) Paint for steel water Tank. (*i*) White lead 27 lbs. boiled linseed oil 3½ pints, raw linseed oil 6 pints, turpentine 1 pint.

(*ii*) Two coats of bitumen solution.

7. Wall Paintings. (*i*) Before applying distemper. Free alkali in new lime and cement plaster rapidly destroys the oil in painting, and prevents it from drying. Do not distemper for 12 months. The walls shall be primed with boiled linseed oil or glue size (Glue in water). Glue size not used if walls are white washed.

First two coats :— White lead, boiled linseed oil. Third coat white lead tinted to desired colour, mixed with raw linseed oil and small portion of turpentine and little of varnish to work as binder. In case of new cement plaster 5 lbs of zinc sulphate in gallons of water before and coat of pure linseed oil before application or with diluted sulphuric or hydrochloric acid

(1 part acid to 50 parts water) and then washed with water. Two coats of paint thinned with turpentine as first and second coat and third thinned with mixture of 3 parts boiled oil to one part of turpentine.

(*ii*) *Painting Damp walls* :—Paraffin 2½ gallons, Benzene 2 gallons and pale resin 14 lbs. Shake well add 24 lbs whiting and grind the mixture well. Keep mixture air tight and apply when required.

(*iii*) *Lamp blacking* :—(For dark rooms and racquet courts). 10 lbs lamp black, 6 lbs white lead, 10 pints boiled linseed oil, 1 pint turpentine ; this will cover 500 sq ft.

(*iv*) *Coat Tarring* :—2 lbs unslaked lime to every gallon of tar and heat it. Put off from fire and add 1 part K. oil, 4 parts tar or ½ pint country spirit to 1 gallon of tar. Apply as hot as possible. 10 lbs for 100 sq ft. Solignum or Creosote are also applied hot (Wood work). A once tarred surface cannot be well painted, unless scraped and good shellac knotting varnish applied in two coats.

8. **Paint Brushes.** Dusting flat surface 12 or 14 size. For girder work size 8. For wood work size 6. For fine work sizes 2 and 4. A round brush is best for painting. New brushes to be used after dipping in water for 2 to 3 hours and dried.

CHAPTER II

1. **Floor Space.** Primary School 10—12 sq ft/pupil. For Secondary School 12—15 sq. ft/pupil. For Colleges 15—20 sq.ft/ pupil. For technical institutions 20—25 sq, ft/ pupil,

2. **Tiles.**

(*i*) Water Repellant.
(*ii*) Fire proof.
(*iii*) Acid resisting.

Sizes :— 4″×4″ ; 8′×4″ ; 5″×10″ ; 6″×12″ ; 8″×8″ ; 10″×10″ and 12″×12″.

Thickness :— ½ ; ¾ and 1 inch.

Chequered steps in sizes :—13″×8″×1½″.

(*a*) *Sitting Rooms* :— Colours are cream, yellow, green maroon mosaic tiles.

(*b*) *Bed Rooms* :— Light green, Dark green and Pink mosaic tiles, for flooring and dark green mosaic tiles in skirting.

(*c*) *Bath rooms* :— Yellow mosaic tiles in dado, pink and maroon colour mosaic tiles in flooring. The panels of the bath tubs are of white carrara marble. Alternatively, Mosaic, precast panels in any colour may be substituted.

(*d*) *Hospital Operation Theatre* :— White Zebrino Indian marble parquet flooring, with Grey Capella. Italian marble as margin. Dado in white carrara Italian Marble. The surgical table is manufactured from white Carrara marble.

3. **Use of water proofing compound for roofs.**

(*i*) Clean the roof thoroughly.

(*ii*) Apply the coat of water proof material like Asphalt, or Jensomastic by means of trowels or palette knife, to an

approximate thickness of 1/8". Material applied should be pressed to ensure satisfactory adhesion and the cracks and pockets should be filled in properly.

(*iii*) 1 cwt per 60 sq ft. of area is sufficient.

(*iv*) Cracks to be opened $\frac{3}{4}$" to 1" and dug out to $1\frac{1}{2}$" to 2 depth and to a bottom width of $\frac{1}{2}$" to $\frac{3}{4}$".

(*v*) Water proofing material to be forced into cracks and should be spread over the surface of roof to a distance of 3" on either side of cracks. Over the actual cracks it should be slightly heaped up in the form of a mould. This will slowly and automatically sink in cracks and seal them. For this painter's trowel or a palette knife is most suitable tool for the purpose.

4. Types of Wooden Trusses.

(*i*) King post truss.

(*ii*) Queen post truss.

(*iii*) Detached verandah roof.

(*i*) *King post truss* :— Tie beam ; wooden wall plates ; struts ; king post ; principal ; purlins ; purlin blocks ; common rafters ; battens Eaves board ; ridge ; Tiles or sheets and ridge sheets.

(*ii*) *Queen post truss* :—Tie beam ; straining beam ; straining sill ; struts ; principals ; purlins ; purlin blocks ; common rafter ; battens ; ridge ; tiles or sheets and ridge tiles or ridge sheets.

(*iii*) *Detached verandah roof* :— Stone or wooden carbel ; bressumer ; common rafter ; battens ; drip of lead ; or G. I. projecting 9" over the roof and let 3" into masonry.

CHAPTER III

Builder's Hardware (Steel, brass, copper and bronze)

1 (*a*) *Hinges* :—(*i*) Butt hinges, cast and Extruded section. (*ii*) Butt hinges loose pin button type. (*iii*) Butt hinges railway type cast and extruded section. (*iv*) Hinges joint railway type. (*v*) Spring hinges single and double action, (*vi*) Parliamentry hinges. (*vii*) Rising hinges. (*viii*) Ventilator hinges (pivot). (*ix*) Swing door hinges. (*x*) Cleat hook. (*xi*) Turn buttons.

(*b*) *Bolts* :— (*i*) Tower bolts sectional, (*ii*) Skeleton bolts sectional. (*iii*) Pressed shaft bolts. (*iv*) Barrel bolts with shoot. (*v*) Flush bolts, (*iv*) Sunk slide, and round shoot.

(*c*) *Aldrops* :— (*i*) Screw fitting. (*ii*) Round guides.

(*d*) *Door latches* :— (*i*) Sectional flats. (*ii*) Nut fitting. (*iii*) Round rod, 5/8" dia and ¾" dia. (*iv*) Curved pan, screw fitting or nut fitting. (*v*) Cast light type.

(*e*) *Casement Window Adjusters* :—

(*i*) Heavy type.

(*ii*) Light type.

(*iii*) When open.

(*f*) *Hooks and Eyes.*

(*g*) *Quadrant stays.*

(*h*) *Safe-Hasps and staples.*

(*i*) *Door and window handle* :

(*i*) Bow handle.

(*ii*) Plate type.

(*iii*) Sunk handles.

(*k*) *Casement Window Fasteners.*

(*l*) *Locks and Handle* :

(*i*) Single and Double locking, arrangement.

(*ii*) Bath room latch.

(*iii*) Baby latch.

(*m*) *Door Knobs.*

(*n*) *Door stop and holders* :

(*i*) Foot door stopper.

(*ii*) Handdoor stopper and holders.

(*iii*) Folding handles.

(*iv*) Bow handles.

(*o*) *Angle plate.*

(*ii*) Socket.

(*iii*) Turn buttons.

(*iv*) Sash buttons.

(*v*) Sash ring.

(*vi*) Sash eye.

(*vii*) Rod socket.

(*p*) *Coat and Hat Hooks.*

(*q*) *Peeping plates.*

(*r*) *Bath room fittings.*

(*i*) Towel rails.

(*ii*) Glass shelves.

(*iii*) Soap cases.

(*s*) *Hand Rails, brackets.*

2. **Ladders.** The width of ladder to be min. 13 .Folding ladders with platform are available and are used by Electric and Fire purposes. Folding ladders are from 5 ft. to 50 ft. in height.

3. **Tools and Plants.**

(*i*) *Shovels* :—(*a*) Loco. (*b*) Round mouth. (*c*) Square mouth.

(*ii*) *Ballast Fork.*

(*iii*) *Pronge* : (*a*) Vine Hoe. (*b*) Square, flat and diamond.

(*iv*) *Kodallie.*

(*v*) *Hammers* :

(*a*) Engineer's ball, pein.

(*b*) Cross pein.

(*c*) Stone Breaking ove eye hammer.

(*d*) Sledge Double faced.

(*e*) sledge staight pein hammer.

(*vi*) *Carpenter's Adze.*

(*vii*) *Rill Hook.*

(*viii*) *Nails and screws* :—

(*a*) Cone-headed nail.

(*b*) Bolt and nut with nicked mushroom.

(*c*) Counter sunk head screw.

(*d*) Cheese head screw.

(*ix*) Belt fastener.

(*x*) Yankee axe.

CHAPTER IV

Woven Wire Netting and Perforated Metal

(*i*) *Wire cloth of* :—Commercial bronze, phosphor bronze, galvanized steel copper, galvanized iron, iron, mild steel, tinned steel, tinned copper, brass and tinned brass.

Mesh	S.W G.	Inch-wire
2½	6	·192
4	12	·104
12	19	·040
24	25	·020
40	32	·0108

(*ii*) *Heavy wire screening.*

Mesh	S.W.G.	Galvanized iron, Galvanized steel, Mild steel, Copper and Brass.					
		(*iii*) *Round holes pattern.*					
¼"	10						
5/16"	12	Hole	Dia.	Thick	Hole	Dia.	Thick
5/32"	18	—	·266"	6·75mm.	10½	·143"	3·63mm
3/32"	20	11	·472"	4·36mm.	9	·097"	2·45 ,,
5"	16				5½	·043"	1·09 ,,

(*iv*) Twilled woven. 20×20 mesh×21 S.W.G.

(*v*) Woven wire clear way mesh. Plain and pressed.

(*vi*) Perforated metal. Staggered, straight, slot and oblong, (in steel, mild steel, copper, brass and zinc).

(*vii*) Square end slots	Size	Thickness
	·750″×·0625″	19·05×1·59 mm.
	·812″×·043″	2·06×1·1 mm.

(*viii*) Brass and copper centrifugal linings.

(*ix*) Elongated conical slots (in copper only) :

(*a*) Perforation—3·8 mm.×0·3 mm. straight slot.

(*b*) Perforation—3·8 mm.×0·3 mm tapper slot.

(*x*) Perforated round holes in brass and copper, from 0·86 to 1·75 mm. dia.

(*xi*) Expanded metal, from $\frac{1}{4}$″ to 4″ mesh.

(*xii*) G.I. Hexagonal mesh wire nettings :

In rolls of 150 ft. and 3 ft. width, $\frac{1}{4}$″ to 4″ mesh and 19, 20 and 22 wire gauge.

(*xiii*) Barbed wire. Galvanized steel, 4 pointed. 3″, 4″, 5″ and 6″ apart—1 cwt. = 1500 ft. long.

(*xiv*) Wire fence. 110 yards—40″ to 48″ high in different gauges of wires and bars

(*xv*) Flexible steel wire rope.

a. Decimal Equivalents of Imperial Standard Wire Gauge

Gauge	Fraction of an inch	Metric Equivalent in millimetres	Gauge	Fraction of an inch	Metric Equivalent in millimetres
1	·300	7·620	26	·018	0·457
2	·276	7·010	27	·0164	0·4166
3	·252	6·401	28	·0148	0·3759
4	·232	5·893	29	·0136	0·3454
5	·212	4 385	30	·0124	0·3150
6	·192	4·877	31	·0116	0·2926
7	·176	4·470	32	·0108	0·2743
8	·160	4·064	33	·0124	0 3150
9	·144	3·658	34	·0092	0·2337
10	·128	3·251	35	·0084	0·2134
11	·116	2·946	36	·0076	0·1930
12	·104	2 642	37	·0068	0·1727
13	·092	2·337	38	·0060	0·1424
14	·080	2 032	39	·0052	0·1321
15	·072	1·829	40	·0048	0·1219
16	·064	1·626	41	·0044	0·1118
17	·056	1·422	42	·0040	0·1016
18	·048	1·219	43	·0036	0·0914
19	·040	1·016	44	·0032	0·0813
20	·036	0·914	45	·0028	0 0711
21	·032	0·813	46	·0024	0·0610
22	·028	0·711	47	·0020	0·058
23	·024	0 610	48	·0016	0·0406
24	·022	0·559	49	0012	0 0305
25	·020	0·508	50	·0010	0·0254

3. Millimetres to inches.

Mill.	Inches	Mill.	Inches	Mill.	Inches	Mill.	Inches
1	·03937	26	1·02363	51	2·00789	76	2 99215
2	·0784	27	1·06300	52	2·04726	77	3·03152
3	·11811	28	1·10237	53	2·08663	78	3 0708
4	·15748	29	1·14174	54	2·12600	79	3·11026
5	·18685	30	1·18111	55	2·16537	80	3·14963
6	·23622	31	1·22048	56	2·20474	81	3·18900
7	·27559	32	1·25985	57	2·24411	82	3·22838
8	·31496	33	1·22922	58	2·28349	83	3·26775
9	·35433	34	1·33859	59	2·32286	84	3·30,62
10	·39370	35	1·37797	60	2·36223	85	3·31149
11	·43307	36	1·41734	61	2·41060	86	3·38586
12	·47245	37	1·45671	62	2·44097	87	3·42523
13	·51182	38	1·49608	63	2·48034	88	3·46460
14	·55119	39	1·53545	64	2·51971	89	3·50397
15	·59056	40	1·54782	65	2·65908	90	3·54334
16	·62993	41	1·61419	66	2·59845	91	3·58271
17	·76930	42	1·65356	67	2·63782	92	3·62208
18	.60867	43	1·69293	68	2·67719	93	3·66145
19	·74804	44	1·73230	69	2·71656	94	3·69082
20	·78471	45	1·77167	70	2·75593	95	3·74019
21	·82678	46	1·81104	71	2·79530	96	3·77946
22	·86615	47	1·85041	72	2·83467	97	3·85893
23	·90552	48	1·88978	73	2·87404	98	3 85830
24	·94489	49	1·92915	74	2·91341	99	3·89767
25	·98426	50	1·96852	75	2·25278	100	3·93704

4. *Liquids* :—

4 gills	=	1 pint
2 pints	=	1 quart
4 quarts	=	1 gallon
8 gallons	=	1 bushel

5. *Weights of Material.*

(*i*) Aluminium sheets 167 lbs/cft.

(*ii*) Asbestos 153—187 lbs/cft.

(*iii*) Brickwork ordinary 112—120 lbs/cft.

(*iv*) Brick work reinforced 115—125 lbs/cft.

(*v*) Cement loose 75—90 lb/cft.

(*vi*) Cement compacted 110 lbs/cft.

(*vii*) Clay 120—130 lbs/cft.

(*viii*) Clinker (for concrete) 90 lbs/cft.

(*ix*) Concrete cement (stone) 130—150 lbs/cft.

(*x*) Concrete reinforced 150 lbs/cft.

(*xi*) Copper sheet 548 lbs/cft.

(*xii*) Copper wire 555 lbs/cft.

(*xi i*) Glass sheets :

1/10″—21 ounce/sq. ft.

1/8″—26 ounce/sq. ft.

5/32″—32 ounce/sq. ft.

(*xiv*) Lead 707 lbs/cft.

(*xv*) Lime stone 116—160 lbs/cft.

(*xvi*) Boulders 90 lbs/cft.

(*xvii*) Unslaked lime 54—66 lbs/cft.

(*xviii*) Slaked fresh lime 36—40 lbs/cft. After 10 days 50 lbs/cft.

(*xix*) Stacked kankar 64 lbs/cft.

(*xx*) Marble 170 lbs/cft.

(*xxi*) Masonry dry stones 130 lbs/cft.

(*xxii*) Shingle 90 lbs/cft.

(*xxiii*) Slate 175—180 lbs/cft.

(*xxiv*) Wood fuel 22 lbs/cft.

(*xxv*) Quantities of materials required for various mixes for 100 cft. of concrete voids in sand 40%, broken stone 45%.

Specific gravity of cement = 3·1.

Mortar :—(100 cft. compact mortar or concrete)

Mix.	Water ratio	Water in gallons per bag	Cement in bags	Sand dry	
1 : 1	·25	2·8	57·5	69	Moist sand 20% more
1 : 1½	·28	3·1	46·5	84·0	
1 : 2	·30	3·3	39·5	94·0	
1 : 2½	·35	3·9	33·5	100·0	
1 : 3	·40	4·4	29·0	105·0	
1 : 4	·53	5·9	22·8	110·0	
1 : 6	·70	7·8	16·3	118·0	
1 : 8	·90	10·0	12·7	112·0	

6. Cement Concrete 100 ft.

Mixture	Water	Cement	Sand	Metal
1 : 1 : 2	30 (10 gln.) per bag	31·9	39·4	78·4
1 : 1½ : 3	·42	22·9	41·2	82·4
1 : 1⅔ : 3⅓	·48	20·6	42·0	82 4
Also known	as 1 : 2 : 2 : 4			
1 : 2 : 2	·42	24·5	59·0	59·0
1 : 2 : 3	·50	21·00	52·0	73·8
1 : 2 : 4	·55	17·00	45·0	85·4
1 : 2½ : 5	·65	14·7	46·0	88·0
1 : 3 : 6	·75	11·50	44·9	89·8
1 : 4 : 8	·95	8·75	48·5	92·2
1 : 5 : 10	1 00	7·00	49·0	98·0

CHAPTER V

1. Height and Weight (In metric terms)

Table of weight in pounds, maunds and seers and kilogram.
(Correct to ½ kilogram)

Pounds	Maunds	Seers	Kgm.
100	1	8·5	45·5
110	1	13·5	50·0
120	1	18·5	54·5
130	1	23·0	59·0
140	1	28·0	63·5
150	1	33·0	68·0
160	1	38·0	72·5
170	2	2·5	77·0

2. Table of height correct to a centimetre.

4′—10″	1·47 metres	5′—6″	1·68 metres
5′—0″	1·52 „	5′—8″	1·73 „
5′—2″	1·58 „	5′—10″	1 78 „
5′—4″	1·63 „	5′—0″	1·84 „

3. Metric System.

Commercial weights are of the following denominations :—

Cast iron weights			Brass/Bronze weights				
Kilogram		Gram	Bullion only		Commodities and Bullion		
			Kilogram		Kilogram	Gram	
50	5	500	20	5	1	005	50 5
20	2	200	10	2		200	20 2
10	1	100				100	10 1

1 Kilogram = 1000 grams = 86 Tolas.

3A. Miles per gallon or per litre and kilometres per litre.

Miles per Gallon	Miles per Litre	Kilometres per Litre
10	2·2	3·5
15	3·3	5·3
20	4·4	7·1
25	5·5	8·9
30	6·6	10·6
35	7·7	12·4
40	8·8	14·2
45	9·9	15·9
50	11·0	17·7

4. Conversion Table (Annas and Pies into Naye Paise).

a—p	nP.	a—p	nP.	a—p	nP.	a—p	nP.
0—3	·02	4—3	·27	8—3	·52	12—3	·77
0—6	·03	4—6	·28	8—6	·53	12—6	·78
0—9	·05	4—9	·30	8—9	·55	12—9	·80
1—0	·06	5—0	·31	9—0	·56	13—0	·81
1—3	·08	5—3	·33	9—3	·58	13—3	·83
1—6	·09	5—6	·34	9—6	·59	13—6	·84
1—9	·11	5—9	·36	9—9	·61	13—9	·86
2—0	·12	6—0	·37	10—0	·62	14—0	·87
2—3	·14	6—3	·39	10—3	·64	14—3	·89
2—6	·16	6—6	·41	10—6	·66	14—6	·91
2—9	·17	6—9	·42	10—9	·67	14—9	·92
3—0	·19	7—0	·44	11—0	·69	15—0	·94
3—3	·20	7—3	·45	11—3	·70	15—3	·95
3—6	·22	7—6	·47	11—6	·72	15—6	·97
3—9	·23	7—9	·48	11—9	·73	15—9	·98
4—0	·25	8—0	·50	12—0	·75	16—0	·100

Re. One=One Hundred Naye Paise

9. Conversion Table in Metric System.

Chhattak	Kilogram	Gram
1	—	58
2	—	117
3	—	175
4	—	233
5	—	292
6	—	350
7	—	408
8	—	467
9	—	525
10	—	583
11	—	642
12	—	700
13	—	758
14	—	815
15	—	875

Seers	Kilogram	Grams
1	—	930
2	1	870
3	2	800
4	3	730
5	4	670
6	5	600
7	6	530
8	7	460
9	8	400
10	9	330
11	10	260
12	11	200
13	12	130
14	13	60
15	14	—
16	14	930
17	15	860
18	16	800
19	17	730
20	18	660
21	19	600
22	20	530
23	21	460
24	22	390
25	23	330
26	24	260
27	25	190
28	26	130
29	27	60
30	27	990
31	28	930
32	29	860
33	30	790
34	31	730
35	32	660
36	33	590
37	34	520
38	35	460
39	36	490
40	37	

40 Seers or one maund=37 Kilograms.

Maund	Kilogram	Grams
1	—	37
2	—	75
3	—	112
4	—	149
5	—	187
6	—	224
7	—	261
8	—	299
9	—	336
10	—	373
11	—	411
12	—	448
13	—	486
14	—	523
15	—	560
16	—	598
17	—	635
18	—	672
19	—	709
20	—	746

1 rnd.=40 Seers.

1 Seer=80 Tolas.

1 Kilogram=1000 Grams.

Metric System—Conversion Tables.

(1) Gallons to Litre		(2) Litres to Gallons	
1	4·55	1	0 22
2	9·09	2	0·44
3	13·64	3	0 66
4	18·18	4	0·88
5	22·73	5	1·10
6	27·28	6	1·32
7	31·82	7	1·54
8	36·37	8	1·76
9	40·91	9	1·98
10	45·46	10	2·20

(3) Pounds to Kilograms		(4) Kilograms to Pounds	
1	0·45	1	2·20
2	0·91	2	4·41
3	1·36	3	6·61
4	1·81	4	8·82
5	2·27	5	11·02
6	2·72	6	13·23
7	3·18	7	15·43
8	3·63	8	17·69
9	4·08	9	19·84
10	4·54	10	22·05

(5) Miles to Kilometres		(6) Kilometres to Miles	
1	1·61	1	0·62
2	3·22	2	1·24
3	4·83	3	1·86
4	6·44	4	2·49
5	8·05	5	3·11
6	9·66	6	3·73
7	11·27	7	4·35
8	12·87	8	4·97
9	14·48	9	5·59
10	16·09	10	6·21

6. Useful Data.

$\pi = 3{\cdot}1416$ or $3{\cdot}142$; $1/\pi = 0{\cdot}3183$; $\pi^2 = 9{\cdot}870$

1 inch = 2·54 cm ; 1 cm. = 0·3937″ ;

1 metre = 100 cm. = 3·281 ft.

= 1·094 yds.

1 yard = 0·9144 metres ;

1 mile = 1760 yds.

= 5280 ft. = 1·609 kilom.

1 sq. in. = 6·451 sq. cm.
1 sq. yd. = 0·8631 sq. m.
1 acre = 4840 sq. yds.
= 43560 sq. ft.
= 0·4047 hectare.
1 cu. in. = 16·39 c. c.
1 litre = 1000 c.c. weighs 1 kg.
1 gal. of water weighs 10 lbs.
= 0·1604 cu. ft.
= 4·543 litres.

Log π = 0·4972
Log 2·718 = 0·4343
Log 0·7854 = $\bar{1}$·8951
Log 62·3 = 1·7945
Log 1728 = 3·2375
Log 0·5236 = $\bar{1}$·7890
Log 0·1604 = $\bar{1}$·2052

1 Kilog = 2⅕ lbs = 1000 gm. = 0·001 tonne
1lb = 16 oz = 7000 grains = 453·6 gm.
1 cu. ft. water weighs 62·3 lbs. 1 radian = 57·3 degrees
1 Knot = 6080 ft. per hour = 1 nautical mile per hour.

To convert common to hyperbolic logarithms multiply by 2·3026 (2·303)

Volts × amperes = watts.

1 horse power = 33000 ft. lbs. min.
= 746 watts.

1 Kilowatt = 102 Kilogram metres per sec (e = 2·718)

Weight in lbs. per cu. in : Cast iron 0·26, Wrought iron 0·28, Steel 0·284, Brass 0·29, Copper 0·319, Lead 0·412, Tin 0·267, Zinc 0·26, Aluminium 0·097, water 0·036, Antimony 0·24, Manganese 0·289.

Body	Position of Axis	Moment of Inertia.
1. Uniform thin rod.	At end, perpendicular to length.	$ML^2/3$
	At middle perpendicular to length.	$ML^2/12$
2. Rectangular Lamina.	Through centre of gravity parallel to side b	$Ma^2/12$
	Through centre of gravity perpendicular to plane	$M(a^2+b^2)/12$

3. Rectangular Solid	Through centre of gravity, perpendicular to face ab	$M(a^2+b^2)/12$
4. Circular Lamina	Any diameter	$Mr^2/4$
	Through centre, perpendicular to plane	$Mr^2/2$
5. Right cylinder	Axis of figure	$Mr^2/2$
	Through centre, perpendicular to axis of fig :	$M\left(\frac{l2}{12}+\frac{r^2}{4}\right)$
6. Hollow Cylinder	Axis of figure.	$M(R^2+r^2)2/2$
7. Sphere	Any diameter	$2Mr^2/5$
8. Rectangle	Through centre, area, parallel to side b	$bd^3/12$
	Axis coinciding with side b	$bd^3/3$.

M denotes mass, L length, *abc* and *d* sides or edges, R or *r* radius of cross section.

$I = I_0 + My^2$ or $I = I_0 + Ay^2$, $K^2 = I \div m$ or $k^2 = I \div A$, where I denotes the moment of inertia about axis, and I_0 about a parallel axis through the centre of gravity, *k* denotes the radius of gyration, A area of cross section and *y* the distance between the axes.

7. Super Elevation and Road Bends.

$$h = \frac{lv^2}{gr} \text{ where}$$

l = width of road in feet.
v = velocity in feet/second.
g = Acceleration due to gravity in feet per sec. per sec. (32·2 feet per second per second)
r = radius of curve in feet.
h = amount of super elevation in feet.

8. Temperature Conversion :—

Fahrenheit to Centigrade—**Centigrade to Fahrenheit**

$$\frac{5(F-32)}{9} \qquad \frac{9C}{8}+32$$

9. Metric Conversion Factor.

To Convert	To	Multiply by	To Convert	To	Multiply by
1. Acres	Sq. metres	4046·85	11. Cubic Yards	Cubic metres	0·76455
2. Centimetres	Inches	0·39370	12. Feet	Metres	0·3048
3. Cubic Centimetres	Cubic Inches	0·61024	13. Force-de-chevel	Horse power	1·0139
4. Cubic Feet	Cubic Metres	0·0283167	14. Gallons (Imperial)	Litres	4·54596
5. Cubic Feet	Litres	28·316	15 Gallons (U.S.)	Litres	3·78553
6. Cubic Inches	Cubic centimetres	16·387	16. Grains	Grams	0·0648
7. Cubic Metres	Cubic Feet	35·3148	17. Grams	Grains	15·43
8. Cubic Metres	Cubic Yards	1·30796	18. Grams	Pounds	0·002205
9. Cubic Metres	Gallons (Imperial)	219·97	19. Grams/Cubic Centimetre	Pounds/Cubic Foot	62·4
10. Cubic Metres	Gallons (U.S.)	264·17	20. Horse power	Force-de-chavel	0·9863
			21. Hundredweight	Kilogram	50·8024

Table 9—Continued

To Convert	To	Multiply by	To Convert	To	Multiply by
22. Inches	Centimetres	2·54	37. Pounds/sq. ft.	Kilogram/sq. metre	4·882
23. Kilogram	Pounds	2·20462	38. Pounds/sq. inch	Kilogram/sq. Centimetre	0·703
24. Kilogram/Sq. Centimetre	Pounds/sq. inch	14·22	39. Sq. Centimetre	Sq. inches	0·15500
25. Kilometre	Miles	0·62137	40. Sq. Feet	Sq. Metres	0·9290
26. Litres	Gallons(Imp.)	0·219975	41. Sq. Inches	Sq. Centimetres	6·4516
27. Litres	Gallons(U.S.)	0·264178	42. Sq. Kilometre	Sq. Mile	0·38610
28. Metres	Feet	3·28084	43. Sq. Metres	Sq. Feet	10·764
29. Metres	Inches	39·37	44. Sq. Metres	Sq. Yards	1·196
30. Metres	Yards	1·09361	45. Sq. Miles	Sq. Kilometres	2·58998
31. Miles	Kilometres	1·60934	46. Sq Yards	Sq. Metres	0·836126
32. Millimetres	Inches	0·03937	47. Tons (British)	Tons (Metric)	1·01605
33. Ounces	Grams	28 3495	48. Tons (U.S.) Short	Tons (Metric)	0·907185
34. Pints (Imp.)	Litres	0·56825	49. Tons (Metric)	Tons (British)	0·98421
35. Pints U.S.)	Litres	0·47 :	50. Tons (Metric)	Tons (U.S.) Short	1·10231
36. Pounds	Kilogram	0·453592	51. Yards	Metres	0·9144

(10) Practical English Equivalent of Metric—Stone Sizes.

Metric Size	Equivalent
10-15 cm.	6 in - 4 in
6-8 cm.	3 in.
4-6 cm.	2½ in.
2-5 cm.	2 in.
2-4 cm.	1½ in.
2-6 cm.	2½ in - 1 in
10-25 cm.	1 in
10-20 cm.	3/4 in
5-20 m.m.	1/2 in
5-10 m.m.	3/8 in.
2-5 m.m.	1/4 in.
1-3 m.m.	1/8 in.
0-20 m.m.	1/2" to dust
0-5 m. m.	1/4" to dust
0-2 m.m.	Dust

For Application of Liquids
Sq. yards per gallon and Gallons yards — to — Litres per sq. metre and Kilograms per sq metre

	Litres per sq. Metre	Kilogram/sq. metre	
		Sp. Gr. =1	Sp. Gr. =1·2
2½ gallons per sq. yd	13·59		16·27
2¼ gallons/sq. yd.	12·26		14 65
2 gallons/sq. yd.	10·87		13·02
1¾ gallons/sq. yd.	9·51		11·39
1½ gallons/sq. yd.	8·16		9·76
1¼ gallons/sq. yd.	6·80		8·14
1 gallons/sq. yd.	5·44	Same as Litres per sq. metre.	6·51
2 sq. yd./gallon	2·72		3·26
3 sq. yds./gallon	1·81		2·17
4 sq. yds./gallon	1·36		1·63
5 sq. yds./gallon	1·09		1·30
6 sq. yds./gallon	0·91		1·09
7 sq. yds./gallon	0·78		0·93
8 sq. yds./gallon	0·68		0·81
9 sq. yds./gallon	0·60		0·72
10 sq. yds./gallon	0·54		0·65

Assume Sp. Gr. = 1 for Emulsions/Bitumen
Sp. Gr. = 1·2 for tars.

12. **Calculation Chart :—**

Decimal parts of a Foot from 1/8 to 7/8 of an Inch

	In. Dec. of Ft.		In. Dec. of Ft.		In. Dec. of Ft.		In. Dec. of Ft.
	1/8·010416		1/8 093750		1/8·177083		1/8·260416
	1/4·020833		1/4·104166		1/4·187500		1/4·270833
0″	3/8·031250	1″	3/8·114583	2″	3/8·197916	3″	3/8·281250
	1/2·041666	·083333′	1/2·125000	·166666′	1/2·208333	·250	1/2·291666
	5/8·052083		5/8·135416		5/8·218750		5/8·302083
	3/4·062500		3/4·145833		3/4·22916		3/4·312500
	7/8·072916		7/8·156250		7/8·239583		7/8·322916
	1/8·343750		1/8·427083		1/8·510416		1/8·593750
	1/4·354166		1/4·437500		1/4·510416	7″	1/4·604166
4″	3/8·364583	5″	3/8·447916	′	3/8·331250		3/8·614831
·333333′	1/2·375000	·416666′	1/2·458333	·; ′	1/2·541666	·583333′	1/2·625000
	5/8·385416		5/8·468750		5/8·552083		5/8·635416
	3/4·395833		3/4·479166		3/4·562500		3/4·645833
	7/8·406250		7/8·489583		7/8·572916		7/8·656250
	1/8·677083		1/8·760416		1/8·843750		1/8·927083
	1/4·687500		1/4·770833		1/4·854166		1/4·937500
8″	3/8·697916	9″	3/8·781250	10″	3/8·864583	11″	3/8·947916
·666666	1/2·708333	·750	1/2·791666	·833333	1/2·875000	·916666	1/2·958333
	5/8·718750		5/8·802083		5/8·885416		5/8·968750
	3/4·729166		3/4·812500		3/4·895833		3/4·979166
	7/8·739583		7/8·906250		7/8·906250		7/8·989583

25. Calculation Chart for decimal parts of a gross

Dozens		1	2	3	4	5	6	7	8	9	10	11
Single		12 ·0833	24 ·1667	36 ·2500	48 ·3333	60 ·4167	72 ·5000	84 ·5833	96 ·6667	108 ·7500	120 ·8333	132 ·9167
1	1 ·0069	13 1—1 ·0903	25 2—1 ·1736	37 3—1 ·2569	49 4—1 ·3403	61 5—1 ·4236	73 6—1 ·5069	85 7—1 ·5903	97 8—1 ·6736	109 9—1 ·7569	121 10—1 ·8403	133 11—1 ·9236
2	2 ·0139	14 1—2 ·0972	26 2—2 ·1806	38 3—2 ·2639	50 4—2 ·3472	62 5—2 ·4309	64 6—2 ·5139	86 7—2 ·5972	98 8—2 ·6806	110 9—2 ·7639	122 10—2 ·8472	134 11—2 ·9306
3	3 ·0208	15 1—3 ·1042	27 2—3 ·1875	39 3—3 ·2708	51 4—3 ·3542	63 5—3 ·4375	75 6—3 ·5208	87 7—3 ·6042	99 8—3 ·6875	111 9—3 ·7708	123 10—3 ·8542	135 11—3 ·9375
4	4 ·0278	16 1—4 ·1111	28 2—4 ·1944	40 3—4 ·2778	52 4—4 ·3611	64 5—4 ·4444	76 6—4 ·5278	88 7—4 ·6111	100 8—4 ·6944	112 9—4 ·7778	124 10—4 ·8611	136 11—4 ·9444
5	5 ·0347	17 1—5 ·1181	29 2—5 ·2014	41 3—5 ·2847	53 4—5 ·3681	65 5—5 ·4514	77 6—5 ·5347	89 7—5 ·6181	101 8—5 ·7014	113 9—5 ·7847	125 10—5 ·8681	137 11—5 ·9514

Table 13—continued.

Dozens		1	2	3	4	5	6	7	8	9	10	
	6	18	30	42	54	66	78	90	102	114	126	138
6		1—6	2—6	3—6	4—6	5—6	6—6	7—6	8—6	9—6	10—6	11—6
	·0417	·1250	·2083	·2917	·3750	·4583	·5417	·6250	·7083	·7917	·8750	·9583
	7	19	31	43	55	67	79	91	103	115	127	139
7		1—7	2—7	2—7	4—7	5—7	6—7	7—7	8—7	9—6	10—7	11—7
	·0486	·1319	·2153	·2980	·3819	·4653	·5486	·6319	·7153	·7986	·8819	·965
	8	20	32	44	60	68	80	92	104	116	128	140
8		1—8	2—8	3—8	4—8	5—8	6—8	7—8	8—8	9—8	10—8	11—8
	·0556	·1389	·2222	·3056	·3889	·4722	·5556	·6389	·7222	·8056	·8889	·9722
	9	21	33	45	61	69	81	93	105	117	129	141
9		1—9	2—9	3—9	4—9	5—9	6—9	7—9	8—9	0—9	10—9	11—9
	·0625	·1458	·2292	·3125	·3958	·4792	·5625	·6458	·7292	·8125	·8958	·9792
	10	22	34	46	62	70	82	94	106	118	130	142
10		1—10	2—10	3—10	4—10	5—10	6—10	7—10	8—10	9—10	10—10	11—10
	·0694	·1527	·2361	·3194	·4028	·4861	·5694	·6528	·7361	·8194	·9028	·9861
	11	23	35	47	63	71	83	95	107	119	131	143
11		1—11	2—11	3—11	4—11	5—11	6—11	7—11	8—11	9—11	10—11	11—11
	·0764	·1597	·2431	·3264	·4097	·4931	·5764	·6597	·7431	·8264	·9097	9930

14. Chart for Qrs. & Lbs. in Decimals of a Ton.

Qrs.	Lbs.	Tons	Qrs.	Lbs.	Tons	Qrs.	Lbs.	Tons	Qrs.	Lbs.	Tons
0	½	·00022	1	0	·0125	2	0	·025	3	0	·0375
0	1	·000446	1	1	·012946	2	1	·025446	3	1	·037946
0	2	·000893	1	2	·013393	2	2	·025893	3	2	·038393
0	3	·001339	1	3	·013839	2	3	·026339	3	3	·038839
0	4	·001786	1	4	·014286	2	4	·026786	3	4	·039286
0	5	·002232	1	5	·014732	2	5	·027232	3	5	·039732
0	6	·002679	1	6	·015179	2	6	·027679	3	6	·040179
0	7	·003125	1	7	·015625	2	7	·028125	3	7	·040625
0	8	·003571	1	8	·016071	2	8	·028571	3	8	·041071
0	9	·004018	1	9	·01651	2	9	·029018	3	9	·041518
0	10	·004464	1	10	·016964	2	10	·029464	3	10	·041964
0	11	·004911	1	11	·017411	2	11	·029911	3	11	·042411
0	12	·005357	1	12	·017857	2	12	·030357	3	12	·042857
0	13	·005804	1	13	·018304	2	13	·030804	3	13	·043304

Table 14—continued

Qrs.	Lbs.	Tons	Qrs.	Lbs.	Tons	Qrs.	Lbs.	Tons.	Qrs.	Lbs.	Tons
0	14	·006250	1	14	·018750	2	14	·031250	3	14	·043750
0	15	·006696	1	15	·019196	2	15	·031696	3	15	·044196
0	16	·007143	1	16	·019643	2	16	·032143	3	16	·044643
0	17	·007589	1	17	·020089	2	17	·032589	3	17	·045089
0	18	·008036	1	18	·020536	2	18	·033036	3	18	·045536
0	19	·008482	1	19	·020982	2	19	·033482	3	19	·045982
0	20	·008929	1	20	·021429	2	20	·033929	3	20	·046429
0	21	·009375	1	21	·021875	2	21	·03475	3	21	·046875
0	22	·009821	1	22	·022321	2	22	·034821	3	22	·047321
0	23	·010268	1	23	·022768	2	23	·035268	3	23	·044768
0	24	·010714	1	24	·023214	2	24	·035714	3	24	·048214
0	25	·011161	1	25	·023661	2	25	·036161	3	25	·048661
0	26	·011607	1	26	·024107	2	26	·036607	3	26	·049107
0	27	·012054	1	27	·024554	2	27	·037054	3	27	·049551

15. Chart of Qrs and Lbs in Decimals of Cwt.

Qrs	Lbs	Cwts	Qrs	Lbs	Cwt	Qrs	Lbs	Cwt	Qrs	Lbs	Cwt
0	1/2	·0045	1	0	·2500	2	0	·5000	3	0	·7500
0	1	·0089	1	1	·2589	2	1	·5089	3	1	·7589
0	2	·0179	1	2	·2679	2	2	·5179	3	2	·7679
0	3	·0268	1	3	·2768	2	3	·5268	3	3	·7768
0	4	·0357	1		·2857	2	4	·5357	3	4	·7857
0	5	·0446	1	5	·2946	2	5	·5446	3	5	·7946
0	6	·0536	1	6	·3036	2	6	·5536	3	6	·8036
0	7	·0625	1	7	·3125	2		·5625	3	7	·8125
0	8	·0714	1	8	·3214	2	8	·5714	3	8	·8214
0	9	·0804	1	9	·3304	2	9	·5804	3	9	·8304
0	10	·0893	1	10	·3393	2	10	·5893	3	10	·8393
0	11	·0982	1	11	·3482	2	11	·5982	3	11	·8482
0	12	·1071	1	12	·3571	2	12	·6071	3	12	·8571
0	13	·1161	1	13	·3661	2	13	·6161	3	13	·8661

Table 15—continued

Qrs.	Lbs.	Cwts.	Qrs.	Lbs.	Cwt.	Qrs.	Lbs.	Cwt.	Qrs.	Lbs.	Cwt.
0	14	·1250	1	14	·3750	2	14	·6250	3	14	·8750
0	15	·1339	1	15	·3839	2	15	·6339	3	15	·8839
0	16	·1429	1	16	·3929	2	16	·6429	3	16	·8929
0	17	·1518	1	17	·4018	2	17	·6518	3	17	·9018
0	18	·1607	1	18	·4107	2	18	·6607	3	18	·9107
0	19	·1696	1	19	·4196	2	19	·6696	3	19	·9196
0	20	·1786	1	20	·4286	2	20	·6786	3	20	·9286
0	21	·1875	1	21	·4375	2	21	·6875	3	21	·9375
0	22	·1964	1	22	·4464	2	22	·6964	3	22	·9464
0	23	·2054	1	23	·4554	2	23	·7054	3	23	·9554
0	24	·2143	1	24	·4643	2	24	·7143	3	24	·9643
0	25	·2232	1	25	·4732	2	25	·7232	3	25	·9732
0	26	·3321	1	26	·4821	2	26	·7321	3	26	·9821
0	27	·2411	1	27	·4911	2	27	·7411	3	27	·9911

Water Proof Mud Plaster

In villages mud plaster to house is a common affair. The surface of this generally wears out during rains. It is scoured out with water and is washed off. There are three methods to make it water proof and resistant to rains.

1. The earth which is used to make the paste of plaster should be free from soft, slippery portion and should not have much sand. It is better to add 2 seers of wheat husk to 100 cft. of earth and chaff should be properly mixed. This mixture should be kept wet and churned up daily for at least a week.

By this better plaster is made and husk gets decomposed.

To see if the plaster is ready, it should be tried on a piece of wall. On drying up if it does not crack, the plaster is ready. If it cracks, a little quantity of sand may be mixed in the ready mixture. If there is exact quantity of sand in the paste, plaster does not crack.

Cut back. Cut back is mixture of bitumen, kerosene oil and wax. To make it, use 8/100 mark (Penetration) Bitumen 100 lbs of bitumen properly heated, add 20 lbs K. oil little by little. In between this operation it is to be mixed properly. Even after full solution is mixed up, it should be mixed for five minutes more. Now 1 lb. of wax should be heated and dissolved slowly in this mixture. It is better if the mixture is stirred up for a long time so that all items are dissolved properly. 4 lbs. of this cut back solution may be added to 100 cft. of earth. The paste of plaster should be properly churned and mixed up.

Now the plaster is ready this may be used and applied in usual way.

Cowdung Wash. When this plaster dries up, cowdung wash is necessary.

For wash, 1 part cowdung, 1 part earth are mixed up. In this solution for 100 cft. of solution put 4 lbs. of cut back.

2. In this method, plaster is made as 1st method and is applied as usual. After it has dried up, undermentioned solution is applied.

This solution consists of 3 parts of slaked lime, 3½ parts of very thin sand should be mixed with iron tool.

Then take a cake of Sunlight soap and mix it in 4 gallons of water. This lather soap and its water should be mixed with the mixture of lime and sand in such a way that a solution is made. It is left to be settled for at least 4 hours. After this 4 parts of cement are to be mixed. This solution should be so thin that it can be applied by brush.

Before applying this solution the plaster surface should by wetted with water. As far as possible this liquid may be applied in the evening after working hours, so that it may get sufficient time to dry up. In all 3 coats of this solution are applied. In between two coats there should be a gap of at least 24 hours.

3. In this method also, plaster as in 1st method is prepared. After the plaster is dried up, a coat of silicon solution is applied. This solution is made by mixing 2% of silicon in water.

This should be taken into consideration that the silicon solution is not applied on the surface which have cracks.

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